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The Dock & Harbour Authority

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No. 429

Vol. XXXVII.

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Editorial Comments

The Port of Cork.

Situated almost in the centre of the southern sea-board of Ireland, facing south to the Atlantic and within ensy reach of the southern and western ports of England, the Port of Cork, with its fine natural harbour, early became the export centre for the agricultural products of the southern counties of Ireland. Cobh, in the Lower Harbour, perhaps better known by its former designation of Queenstown, also became a port of call for Atlantic shipping. Indeed, it was from the Port of Cork in 1838 that the historic first westbound steamship, the "Sirius," crossed the Atlantic to America in the then record time of seventeen days.

We are indebted to Mr. F. O'C. Saunders, Chief Engineer of the Port of Cork, for the article on a following page which describes the development from the 18th century of the Upper Harbour, with particular emphasis on the types of construction adopted in the passing years to obtain adequate quays and depth of water for the growing needs of shipping.

From an engineering point of view, this review is of considerable interest. The history of the development is a record of continued effort in the face of many difficulties, in part due to lack of finance and in part to political and economic conditions and to intervening wars. In company with many other port authorities, Cork Harbour Commissioners are to-day faced with the problem of keeping pace with the ever-increasing length and draught of ships. The post-war steps to re-condition the port however have been taken boldly, as our readers will observe.

A noteworthy scheme to deepen the navigation channels and at the same time to provide additional land for industrial development and quay space has led to the reclamation of a large area of land from the River Lee by the construction of embankments and the pumping ashore of dredged spoil. This site, known as the Tivoli Industrial Area, will eventually have an area of 150 acres, adjacent to deep water and to the main line railway. About ten acres of reclaimed land are now available for immediate occupation.

It is also interesting to note that the Government of Ireland has decided in principle that an airport should be provided at Cork with a view to the establishment of scheduled air services to and from the City. The Pork of Cork is already well served by road, rail and sea, and this proposal appears to be a realistic step towards serving the modern need for integrated transport facilities.

Torsion Resisting Dolphins

In the past decade or so significant developments have been made in the design of impact-resisting maritime structures such as jetties, dolphins and fender systems. Cases in point are the non-braced steel piled fenders developed by the Civil Engineer-in-Chief's Department of the Admiralty; the energy-absorbing gravity fenders designed by Professor A. L. Baker: the use of rubber in energy-absorbing fenders, as described by Mr. A. R. Smee (this Journal, August 1954); and the flexible berthing beam, described in an article by Mr. H. Ridehalgh (this Journal, May 1955).

On the Continent also considerable progress has been made, the dolphins constructed in Amsterdam and described by Mr. Risselada in the June and July 1954 issues of this Journal being examples.

In this issue we now publish an article by Herr Hugo Minnich in which is described a further development in the design of isolated dolphins.

In the design of such structures certain broad assumptions must be made, amongst which are the magnitude and distribution of the impact and the ground conditions. The structural members must of necessity be designed for "the worst case" and, because of the degree of uncertainty underlying these assumptions, will, for most of their life, be stressed well below an economic value. Within the limits imposed by this factor, however, important economies are possible and the author claims that the system of "Torsional bracing" developed by his brother, Willy Minnich, makes such economies possible.

The author states that in the case of dolphins with parallel piles and with horizontal bracing connected to the piles by loose or hinged joints, where impacts are other than centrally applied, the dolphin is capable of absorbing only about half the energy which it could absorb under centrally applied impact and is thus uneconomically designed.

The principle of the "Willy Minnich" dolphin lies in connecting individual piles to a system of torsional bracing by torsion resisting joints. By this means the moment arising from the eccentric impact is absorbed partly by deflecting the piles and partly by twisting them and, by suitable application, this enables all the piles to be more or less equally stressed, thus leading to an inherent economy compared with other systems.

The system has been patented and has been applied in practice. A large dolphin designed on this principle by Herr Willy Minnich for the Ilsede-Peine Works was constructed in New Guinea in 1953.

Flags of Convenience

The International Chamber of Shipping has not yet found itself able to issue the survey of flags of convenience it has under revision, and a week or two may elapse before the document is published. New points are continually arising—as, for example, the law just signed by the President of Chile that 50 per cent. of her international and the whole of her coastal trade shall be reserved to Chilean-flag ships. Four countries, the United Kingdom, America, Sweden and Norway have joined in protest against this discriminatory measure, for although the Chilean merchant fleet may not be large enough to carry the country's trade — it is only just over 200,000 tons gross—the legislation is deplored by other maritime countries.

The International Law Commission which has been considering the future règime governing the freedom and usage of the high seas is expected to complete its work at its current session in Geneva. In a volume prepared by the Codification Division of the United Nations Office of Legal Affairs it is noted that there is "no uniformity" in the conditions on which States allow merchant ships to fly their flags. It quotes an earlier report on the règime of the high seas by Mr. J. P. A. Francois, the noted Netherlands legal authority and a member of the International Law Commission, who said: "the acknowledged freedom of a State to lay down the conditions on which it shall grant its nationality to ships is, of necessity, based on the concept that the national element with regard to a ship and the manner in which it is used have a wide variety of application, and that a certain minimum should be guaranteed in the general interest of all who use the high seas." The International Law Commission seems to have particularised on this general view, for, as stated in our last issue, it approved an article which lays down that ships have the nationality of the State whose flag they are

Editorial Comments—continued

entitled to fly, and that there must be a " genuine link " between the State and the ship. How this is to be translated into practice may be one of the subjects considered by the General Assembly of the League of Nations this autumn.

The International Law Commission has been engaged since 1949 upon the task of codifying the law of the high seas and territorial waters and most people will hope that positive recommendations will mark the end of their work.

Pneumatic Breakwater Experiments

The efficacy of pneumatic breakwaters for protecting harbours, shipping in exposed anchorages, and salvage work continues to be studied in many countries. We have now been informed by the Research Committee for Hydrology, Japan, that a second full-scale test has been carried out under natural conditions at Hajima, off the harbour of Nagasaki, as the continuation of the experiment of last year at Iwojima. The linear dimensions of the new installation were about twice those of the first experiment, brief details of which were published in this Journal last April.

The data obtained from the latest experiment have not been examined in detail, but it is claimed that in a case when the property of waves was simple, waves up to 25 metres in length were annihilated almost completely with air consumption of $1.2m^3/m$ min, keeping the water surface in the large area behind the pneumatic breakwater uniformly calm. This new breakwater therefore showed still better efficiency than the first test, and the further details which are to be published as soon as the harmonic analysis of the wave records is completed, will, no doubt, prove of considerable interest.

Unfortunately the study of this important subject still appears to be receiving insufficient attention in the United Kingdom and, to the best of our knowledge, the advocates for full-scale trials at sea have received no support in official quarters. Despite this, however, we understand that a full-scale trial of a new design of pneumatic breakwater is now being carried out by a private company on the south coast. Should their calculations be correct (and they have already been proved to a certain extent by a previous trial) the results may be of untold value.

This is an encouraging development and it is to be hoped will be successful if only to maintain our national prestige.

" A Comparison of Conventional versus Unitised Cargo Systems"

Ship turnround speed is controlled by a number of factors. These include the layout of the berths at the discharging and loading ports, the facilities provided there, the quality of labour available, the handling methods employed and the efficiency of the port organisation. This question of turnround time is so important to the shipping industry that it is of practical interest that a " Conference" appointed by the United States National Research Council is making it part of a special study. The terms of reference of this body—the Maritime Cargo Transportation Conference—are " to provide guidance on means and techniques leading to the improvement in the sea transport of general cargo."

The M.C.T.C. began its work in 1954 by making a meticulous analysis of the processes involved in taking a complete cargo of miscellaneous goods from New York to Bremerhaven in a conventional cargo vessel, the s.s. " Warrior." Its second study (just published under the title quoted above) approaches the subject in a different way, and attempts to compare the costs in time, money and labour of transporting goods across the sea (a) as separate, individual packages, (b) as palletised unit loads and (c) in containers. Data was obtained from the study of particular shipments of miscellaneous army stores, which were transported from the east coast of the United States of America to Labrador. Each section of the process, from Army Depots in U.S. to Base Warehouse in Canada (eight " segments " in all) was studied separately and in much detail, a description of the methods used and discussion on their implications being set out in the final document.

This document is a book of 163 pages, with 70 illustrations and 100 tables and diagrams. It brings home to the reader that another factor in ship turnround should be added to those mentioned above. This factor is the way in which goods are tendered for shipment—that is, whether the consignments consist, for example, of individual packages (frail or robust) of palletised units (banded or completely " sheathed ") or of container-loads. These differences are important because they affect so much the way goods must be handled and thus the speed with which they can be put into and taken out of sheds, warehouses, road vehicles, railway trucks and ships' holds. Palletised loads and container loads, of course, demand mechanical equipment at every handling.

This interesting and instructive study is reviewed in detail on a following page.

Health Control of Sea and Air Traffic.

The member states of Western European Union now form a single territory for health control of sea and air traffic, as a result of administrative arrangements which have just come into force.

Within this newly-created special area, the seven countries will afford each other health control facilities for air and sea traffic, thus extending the scheme operated by the five-power Brussels Treaty Organisation.

As far as sea traffic is concerned, the Maritime Declaration of Health is no longer required from member countries' vessels plying only between those ports of the seven countries included in the scheme. In normal health circumstances there will therefore be no further need for such vessels to apply for " free pratique " by radio.

An information exchange service has been organised so that the health authorities in member countries can keep in constant touch and can supply each other with particulars of all diseases covered by international health regulations, or any epidemiological incident which would be of interest to the other countries in the scheme; they will also supply any necessary information on the origin and progress of outbreaks and the steps taken to deal with them.

In their efforts to speed international communications, several European organisations have encountered a number of obstacles, including passport and customs inspections and health controls at frontiers. The establishment of a single territory for members of Western European Union means that one of these obstacles, that of health controls, has now been overcome in Western Europe. This is a noteworthy achievement.

Improved Navigational Aids for India.

In order to improve India's coastal navigation the Government of India is to undertake a programme of development of her lighthouses at a cost of over £5 million. The services of two foreign experts have been obtained to assist in the development. Mr. C. H. Bejrock, a Swedish engineer, has been appointed for two years to advise in the construction of a lighthouse at Lushington in the Gulf of Kutch, on the west coast of India. This lighthouse will be built on a site having a depth of 50-ft. of water. Monsoon seas and cyclones are frequent in this area and it is claimed that the completed lighthouse will be unique in technical design and construction for that part of the world. The second adviser, M. Dyminsky, a French engineer, who has been seconded under the U.N. Technical Assistance Programme, is to assist the Indian Lighthouse Department in the installation of electric and ancillary equipment.

India, with its great length of coastline, has in all about 1,800 navigational aids, including both lighthouses and floating aids. The improvements now recommended relate to an improved buoyage system and radio communications between ships and lighthouses. Departmental surveys are in progress for the installation of a chain of radio towers in the Arabian Sea and the Bay of Bengal, particularly at the approaches to the ports of Bombay and Calcutta. Each radio station will have a 350 to 500-ft. tower with long range radio equipment.

In addition to the construction of the Lushington lighthouse on the West Coast, the Government is constructing another lighthouse on the East Coast at Vishakapatam. When completed, this will be one of the most powerful lighthouses in the East, having a seven million candle power flasher with a range of 30 to 40 miles.

The most powerful lighthouse in India at present is at Vengurala, on the Bombay coast. This is equipped with a 120,000 candle-power flasher and has a range of 20 miles. The Lighthouse Department, after carrying out experiments for several years past, claims to have developed a new type of flasher and bulb.

The Port of Cork

Developments of the River Port of Cork City *

By F. O'C. SAUNDERS, B.E., M.Inst.C.E.(Ireland).

Early History.

CORK has a history which dates back to pre-Christian times. Ptolemy mentions the existence of a settlement at Cork in the second century, but it did not assume any importance until the seventh century, when St. Finbarr founded a monastic school there and the city, in due course, grew up around it.

It is recorded that in the fourth century an Irish monarch, who was styled King of Albany, fitted out at Cork a formidable fleet with which he invaded Gaul and Britain. Defeating the Romans, he ravaged their settlements and returned, laden with spoil, to Ireland.

In the ninth century, Cork was invaded by Norsemen who built a fortress there. Several times during the succeeding centuries Cork was burned down by marauding invaders. Danes attacked the City in 851 and again in 917, when a considerable number settled there. In 937 the Norse and Danish settlers in Cork were attacked and defeated by Gellachain of Cashel who destroyed the town and port facilities. The original invaders, however, returned attracted, no doubt by the important maritime situation, and rebuilt their settlements there.

It was by these Scandinavian invaders that Cork's maritime commerce was founded. They traded in such commodities as cloth, corn, honey, wine, furs, hides and fish. Their trade was mainly with English ports, but their ships also sailed to Scandinavia, Russia, Normandy, the Hebrides, Orkney Islands and Iceland.

During ensuing centuries the Port of Cork grew in importance and in the year 1500 a Charter was granted by Henry VII, under which the Mayor of Cork was given jurisdiction over the Port. The growth of the Port was for long periods retarded by wars and economic restrictions, but the slow and steady revival of the country's economic life during the eighteenth and nineteenth centuries resulted in its steady development.

In the early years of the 18th century, the City of Cork was developing eastwards towards the present Upper Harbour and, during the process, a number of marshes were reclaimed and creeks either filled up or covered over, while streets were laid out to a regular plan, some being on the site of the ancient waterways which then became main sewers. Meanwhile, during that century shipping at Cork reached such dimensions that the need for adequate harbour facilities became apparent. Certain Acts of Parliament were passed by the British Parliament whereby the City Corporation received powers to finance improvement of the harbour and river channels out of public funds and the Mayor and Sheriff of Cork were appointed Conservators of the Port with twenty-four commissioners. Despite these Acts, however, little was done to improve the harbour until the middle of the 18th century when certain quay walls were built and the deepening of the river from Blackrock to the Customs House Quays was undertaken. The grants voted for these works proved inadequate and, further funds being refused, the deepening work already begun was abandoned so that, by 1810, heavily laden vessels were again discharging at Cobh and Passage, being unable to proceed further up the river.

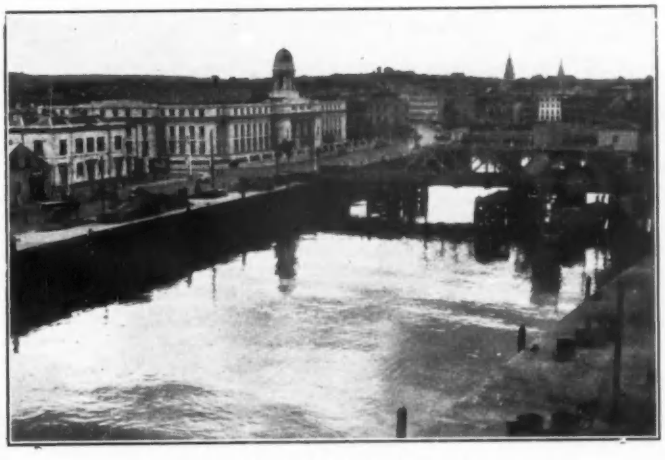
Modern Development.

The first constructive step to improve the Port was taken in 1820 when the Cork Harbour Commissioners, who are still responsible for its management, were constituted under Act of Parliament.

Whilst the Port of Cork is one administrative unit, it comprises two distinct areas: the Lower Harbour with its great sheltered, land-locked basin and natural deep-water channels, one of the finest, safest and most commodious of natural harbours where a large fleet can lie securely at anchor; and the Upper Harbour, an artificially created River Port, which consists of the river channel from Passage West to Cork and the berthage at the Cork City quays.

At the time of the constitution of the Harbour Commission and for some years afterwards, the accommodation for shipping in the Upper Harbour was both antiquated and inadequate. There were no lighthouses or buoys to mark the navigation channels which would only take vessels of 15-ft. draught at spring tides, and at the City berths all vessels had to lie aground. Overseas vessels had to anchor at Passage and discharge part of their cargo before proceeding to Cork.

The years 1849 to 1887 saw the construction of various railways linking Cork with other neighbouring towns and railway services. All these railways were of great service in the development of the Port, and from 1845 onwards a steady improvement took place. The river was dredged, the quays at Cork deepened, and proper lighting and buoys provided in the channels. The improvements thus begun have continued and been extended in succeeding years.



City Hall and South Channel.

The modern Port of Cork fulfils various purposes and it is both a river port and an ocean port. In respect to trade, it is primarily a distributing and exporting terminal and it also constitutes a port of call as well as a transit port.

As regards auxiliary services, it is well served by barge and lighterage facilities, railways and road transport, while ship repair work is carried out at the Rushbrooke Dry Dock and at Haulbowline.

Ample bonded warehouse accommodation is available including cold storage facilities. The regular cross-channel and Continental steamship companies also provide their own storage and transit shed accommodation as well as cattle lairages. The aggregate quayside grain storage capacity including that of the new silos, recently constructed, is 60,000 tons.

The Harbour Commissioners have available for hire a 40-ton shearlegs, a 25 ton fixed electric transporter crane, and a four-ton mobile crane; while at the various quays there are numerous cranes of from 2- to 5-tons capacity. There are also a number of mobile cranes (2- to 5-tons capacity) available for rapid handling of goods on the quays.

The traffic through the Port of Cork comes principally from the neighbouring counties of Cork, Kerry, Waterford, Tipperary and Limerick. Its situation in the centre of a great agricultural and livestock district ensures that its principal exports should consist of provisions and live-stock to Great Britain. Thus the principal

* Based upon a Paper read by the author before the Institution of Civil Engineers of Ireland on 5th March, 1956.

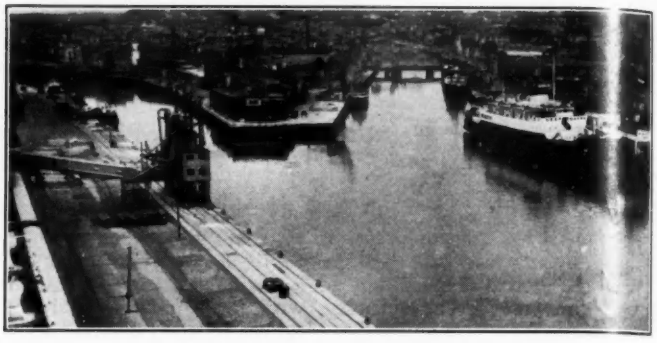
The Port of Cork—continued

exports are: bacon, butter, cheese, eggs, frozen meat, live-stock, poultry, confectionery, together with burnt mineral ores and clay. Imports include cement, coal, feeding stuffs, fertilisers, machinery, motor car parts, oils and fuel oil, rubber, salt, steel and timber.

Development of the Upper Harbour.

The following paragraphs show the lines upon which development and improvement of the Upper Harbour and of the various quays and wharves took place and are of particular interest from an engineering point of view.

In 1845 replacement of the older part of the Navigation Wall, built in 1761, was commenced for the purpose of widening the river below the Custom House. This work was completed in 1864 by the building of Victoria Quay. It extended from the present site of the Electricity Supply Board power station to the Custom House, this part of the river being widened to 500-ft. Previously it had been



South Quays and North Channel.

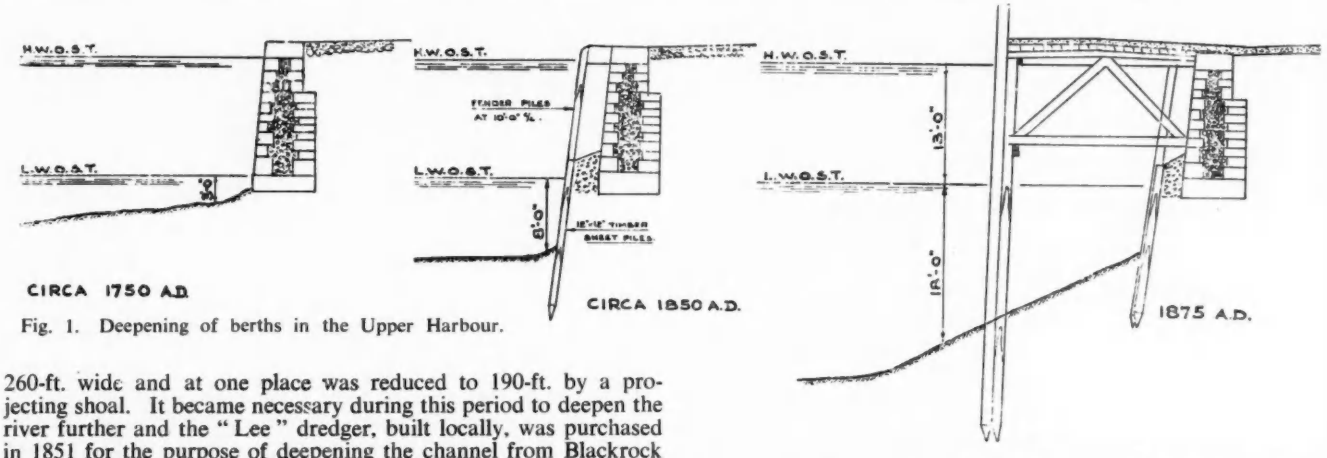
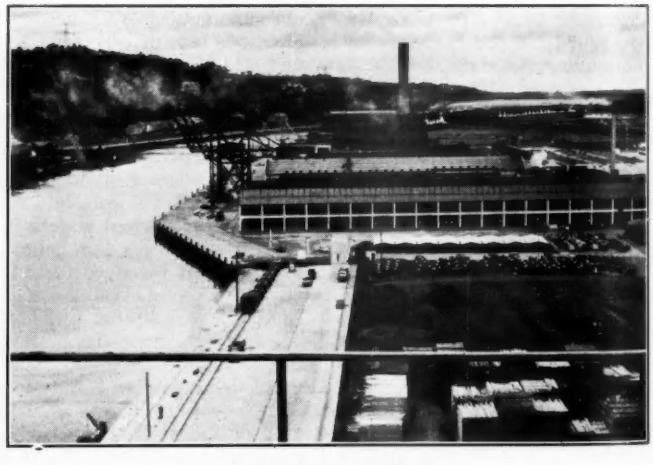


Fig. 1. Deepening of berths in the Upper Harbour.

260-ft. wide and at one place was reduced to 190-ft. by a projecting shoal. It became necessary during this period to deepen the river further and the "Lee" dredger, built locally, was purchased in 1851 for the purpose of deepening the channel from Blackrock up, so making 10-ft. at L.W.O.S.T. from Passage to the city. Deepening of the berths was accomplished by driving timber sheet piling along the toes of the walls. The piles, 11 to 13-in. square, 19 to 23-ft. long and heavily creosoted, were driven 16 to 20-ft. below low water. A continuous walling ran behind them. Every 9-ft. or so a fender pile as high as the wall was driven and fixed firmly to the coping. Between 1857 and 1864 a total length of 18,580-ft. of quays was so piled. A fourth dredger was purchased by the Harbour Commissioners at the commencement of this operation to speed its completion. A great deal of this work is still standing, the timber very sound. This allowed of dredging 7- and 8-ft. of low water alongside the quays. At a later stage much deeper water was made at some of these quays by building timber wharves and dredging outside them to depths appropriate to the width of the new structures. Up to 18-ft. was obtained in this way (Fig. 1). At this period the Harbour Commissioners had two dredgers, one tug, sixteen iron barges of 80-110 tons capacity and four timber barges. In spite of this the river was still too shallow but, it must be pointed out, the disposal of spoil was slow and costly. The dredgers delivered into barges from which the spoil was barrowed ashore to back up the Navigation Wall. The handsome elm lined drive known as "The Marina" was so formed. The power of the "Lee" dredger was increased and the Commissioners purchased two steam self-pumping sea-going trap barges to take the dredging for dumping in deep water at sea. This speeded up the rate of dredging and in 1867 a new programme was initiated to increase the channel depth from 8 to 11-ft. low water from Passage up.

A committee appointed to inspect the local Lighthouses, Buoys and Beacons in Ireland reported to the Board of Trade in 1854 that the channels from the entrance to the Harbour to Cork quays —a distance of twelve miles—had been most effectually marked and defined. When the 11-ft. channel was nearing completion in 1874 Victoria Quay was made a deep water berth by building jetties and dredging to 20-ft. at low water. These were the "South Jetties" a name still retained by a concrete wharf now newly completed. There were seven of these jetties each 43½-ft. long and 20-ft. wide, they were spaced 120-ft. clear of each other. Soon



South Deepwater Quay.

after completion the interjacent spaces were built in, 100-ft. was added and the city had some 1,150-ft. of deep water berthage for overseas ships.

A Cork Improvement Act and a Cork Harbour Act were passed in 1875. The former gave powers to the Cork Corporation to replace two bridges, one, St. Vincent's Bridge at the western end of the city and the other, Anglesea Bridge, a lifting bridge on the south channel a short distance above the Custom House. The Harbour Commissioners were to defray half the cost of the structure replacing the latter. This is Parnell Bridge, opened in 1882. It is a swivel bridge with a clear opening of 50-ft., having 10-ft. depth at L.W.O.S.T. The Cork Harbour Act, 1875, gave the Commisioners power to build a deep water quay on the south bank of the river for a distance of 3,900-ft. eastward of Victoria Quay. The Commissioners obtained a further Act in 1877 empowering them

The Port of Cork—continued

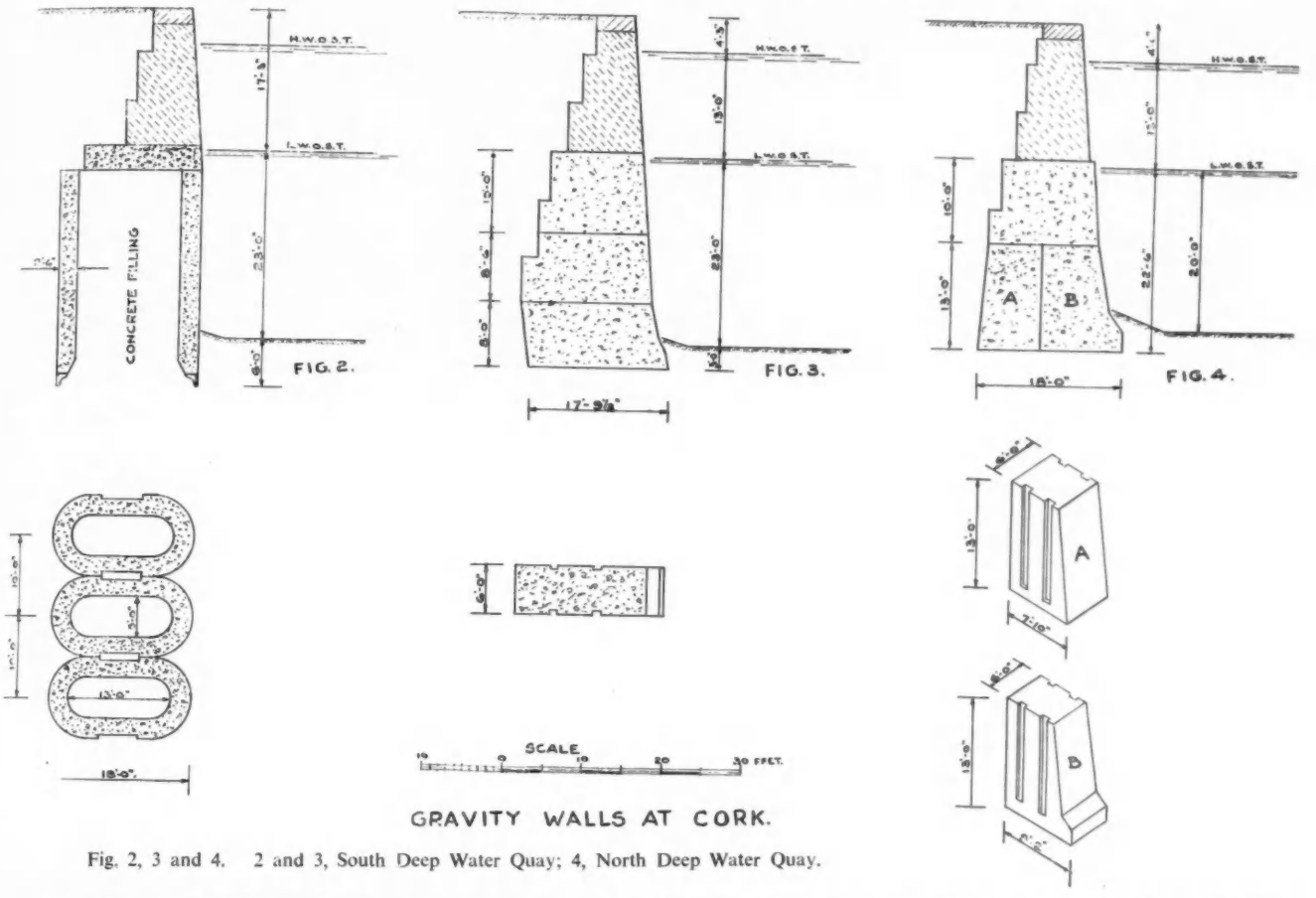


Fig. 2, 3 and 4. 2 and 3, South Deep Water Quay; 4, North Deep Water Quay.

Grain Silos and Mills.

to build another deep water quay on the north side from Penrose Quay to Water Street, a distance of 1,421-ft. and a further deep water quay 600-ft. long outside the railway station at Cobh.

The South Deep Water Quay to give 23-ft. low water was commenced in 1877 and stopped in 1883 after 660-ft. had been completed. The quay was designed with a sub-structure of concrete oval cylinders 18-ft. x 10-ft. with cast iron shoes. They were to be sunk 29-ft. L.W.O.S.T. by grab and kentledge, being extended as they penetrated the ground. They were 26½-ft. high, surmounted by a concrete slab 3-ft. thick x 15-ft. wide. A masonry superstructure rested on the slab (Fig. 2). The work was to be done in the dry in a trench dug out for the purpose. Much difficulty was experienced with the sinking of the cylinders from flooding of the trench owing to pumping failures, from collapse of the trench sides and other causes. After 241-ft. had been constructed the cylinder system was abandoned and the remaining 419-ft. was built on a superstructure of three tiers of massive concrete blocks (Fig. 3) placed under water on a bed made by dredging and levelled off by divers. They rose to 2-ft. over low water.

About this time the Great Southern and Western Railway Co. purchased some of the land lying between Penrose Quay and Water Street, and by agreement the Commissioners obtained powers to build a quay and roadway on the front of this property, the company having preferential use of the quay there.

The North Deep Water Quay was put in hand early in 1878. It was completed in three sections, first working eastward from Penrose Quay then westward from Water Street and thirdly fronting the railway property. The sub-structures of the first two sections consisted of three pre-cast concrete blocks in two tiers, two blocks in the bottom and one on top (Fig. 4). Thirty feet at the Water Street end had a cast-in-situ sub-structure. These two sections occupied about half of the whole length. The middle half was built with a sub-structure of three tiers of blocks similar to the South Deep Water Quay wall. The work was finished early in 1884. It was attended by certain difficulties, chief of which were a deterioration of the face of the in-situ cast sub-structure at the eastern end and excessive dredging of the foundation at another part. The defective concrete was blasted away for a depth of 4-ft. and a height of 8-ft. presumably for the length of 30-ft. The edges of the crater were trimmed back square and good concrete was inserted. The repair was eminently successful. Where the dredger had worked too deep a new foundation of weak gravel concrete was laid and levelled by divers. This quay gave 20-ft. at low water.

During the twenty years up to the completion of the Deep Water Quays many other lesser works had been completed. The New Wall had been replaced virtually over its whole length and it had been extended to Blackrock village. Its completion reclaimed the south slob which became known as City Park. The Passage railway which ran originally close to the New Wall was diverted to

The Port of Cork—continued

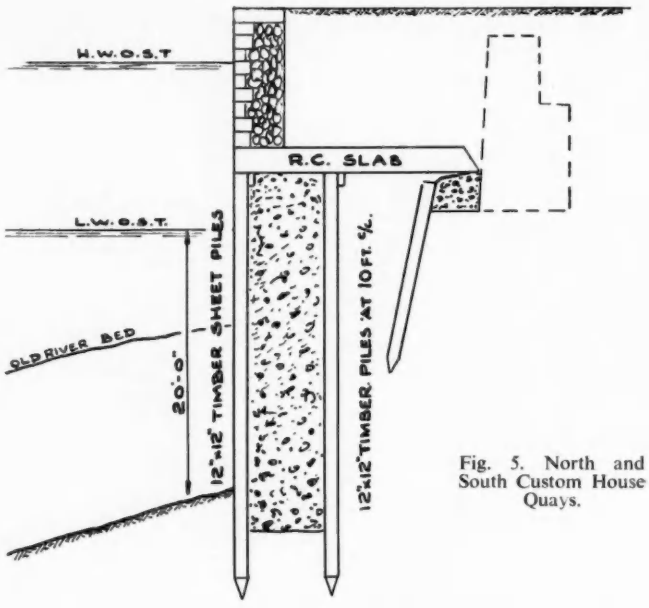


Fig. 5. North and South Custom House Quays.

the south side of the City Park with a new terminus at Albert Street. All of the old rubble walls, of whose condition Nimmo had complained in the early years of the century, had been replaced by cut stone walls. The berths between St. Patrick's Bridge and the site of the North Deep Water Quay had been deepened to 13 and 20-ft. by wharf building.

Coincidental with the construction of the Deep Water Quays the channel from Passage to Cork was further deepened to 14-ft. After completion of these works a general trade depression set in and no further development works were carried out for ten years.

Trade began to improve in 1804 when work started on 1,200-ft. of wharfage along St. Patrick's Quay and Penrose Quay for the Cross-Channel steamers. These wharves, completed in 1896, allowed the steamers to sail at any state of the tide except for about three hours at low water springs. The "Loughmahon" dredger and two 1,200 tons steamer hopper barges, the "Owenabuee" and "Owenacurra," were purchased in 1896 to widen and deepen the channel to 350-ft. and 16-ft. L.W.O.S.T., respectively. The cut was completed in 1904 and there started a programme of quay extension and berth deepening under an act of 1903. The North and South Custom House Quays, each 600-ft., long were reconstructed as shown in Fig. 5. Anderson's Quay (850-ft.) was extended by wharfage as described above (Fig. 1—1875). Similar wharves were built at Albert Quay (900-ft.) and Lapp's Quay (400-ft.) These works all gave depths of 20-ft. L.W.O.S.T. Under the same act the Commissioners acquired and extended the main portion of the Custom House which they opened as new offices in 1906.

The Cork City Railways Act, 1906, authorised the laying of a connecting railway between the Great Southern and Western Railway and the Cork, Bandon and South Coast Railway and the laying of siding on the quays. The connecting railway necessitated the building of a Scherzer type rolling lift bridge over each of the North and South Channels below the existing bridges. The connection was made by 1912 by which time sidings extended 1,300-ft. along Penrose Quay, 1,000-ft. on Anderson's and the North Custom House Quays and 3,000-ft. along the south quays as far as the extremity of the South Deep Water Quay Wall.

In 1917 the development of the Marina Industrial Estate, covering the whole of the City Park and some of the adjacent river front, began when Henry Ford and Son, Ltd., acquired the property and initiated the manufacture of motor cars and tractors in Ireland.

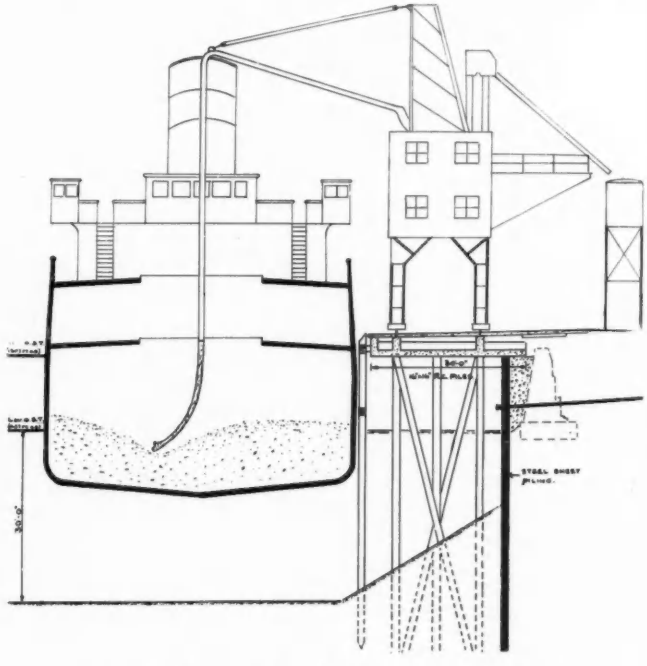


Fig. 7. Pneumatic Grain Plant at Victoria Quay.

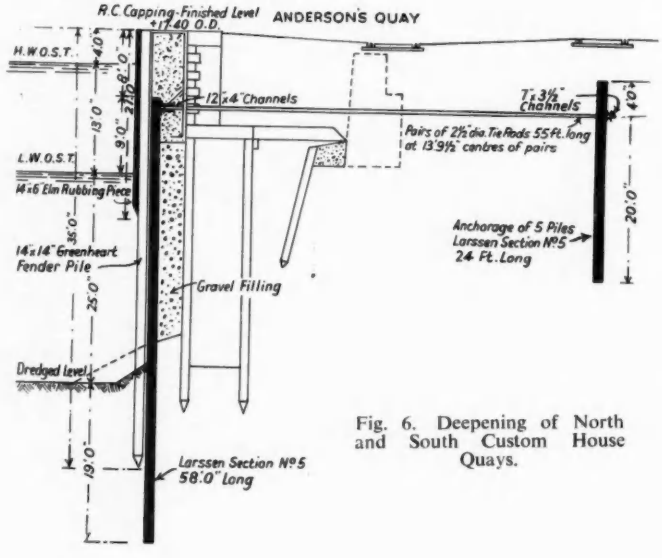

R.C. Capping-Finished Level +17.40 O.D.
ANDERSONS QUAY
H.W.O.S.T.
L.W.O.S.T.
14"x6" Elm Rubbing Piece
12"x4" Channels
7"x3½" Channels
Pairs of 2½" dia. Tie Rods 55 Ft. long at 13'9½" centres of pairs
Anchorage of 5 Piles Larssen Section No.5 24 Ft. Long
14"x14" Greenheart Fender Pile
Gravel Filling
Dredged Level
Larssen Section No.5 58'0" Long

Fig. 6. Deepening of North and South Custom House Quays.

The estate now accommodates the extensive Ford and Dunlop factories, the 60,000-Kw. generating station of the E.S.B., a shirt-making factory, a grain silo and tank farms for the principal oil companies.

When Ford's acquired the City Park it was anticipated that riverside industrial sites would soon become exhausted. This thought and the greatly increased cost of dredging inspired the Commissioners to seek means to deal with these problems and it was decided to utilise the Tivoli Slob, primarily, to cheapen dredging by pumping spoil ashore and, secondly, to utilise the land so made for future industrial development as occasion should arise. They acquired 153 acres of the slob land from the Board of Trade in 1919 and fenced off about 8 acres of it to test the proposals of the Harbour Engineer as to the practicability of liquifying mud, pumping it on to open slob land and expecting it to stay there which did not appeal to some of the Commissioners. A steam-driven pump, 150 h.p., was erected on a specially built jetty. There was an auxiliary pump to mix large quantities of river water with the spoil in the hopper barges to render it capable of being pumped ashore. It was estimated that the spoil would need to be diluted to 90 per

The Port of Cork—continued

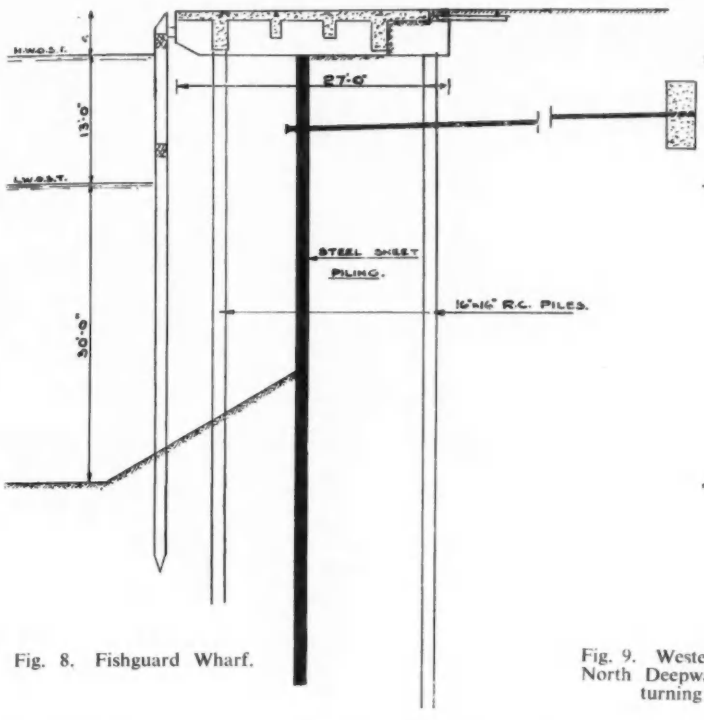


Fig. 8. Fishguard Wharf.

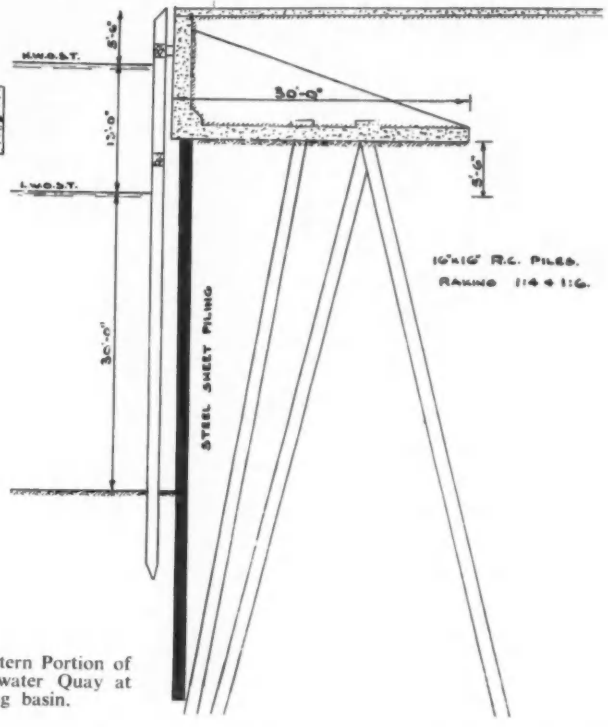


Fig. 9. Western Portion of North Deepwater Quay at turning basin.

cent. water, 10 per cent. solids. The experiment proved practicable and in 1925 pumping ashore began on a regular footing. The reclamation area was open towards Dunkettle and enclosed only on the river side. Of the spoil pumped into it the heavier particles deposited near the pump, the smaller ones travelled on to rest further away. Generally speaking, the spoil settled down to a slope of 1:100 the shore delivery pipe being extended as occasion arose. The pumping station suffered from the defect that the pumps were at a fixed level determined by the size of the hopper barges. This level was too high for the suction of the diluting pump to operate at low water springs which occur about mid-day in Cork. Consequently hoppers had to miss pumping ashore periodically and had then to go to sea, the round trip being about 28 miles. This system operated until after the outbreak of World War II.

During the years between the wars the timber South Jetties was replaced by a concrete structure 30-ft. wide to give 30-ft. low water and the old Fishguard Wharf was also replaced in concrete and a Transit Shed and Passenger Shed were erected on it. The berth was deepened from 13-ft. to 17-ft.

During World War II shipping into Cork was reduced drastically, revenue fell away, dredging was reduced to the bare minimum and at one period was stopped because the only coal available was not able to keep steam up in the dredgers. The only work of any magnitude carried out was the construction of an embankment along the wooden fence used for retention of reclaimed ground at Tivoli. The embankment, 2,500-ft. long, was partly stone and partly concrete faced.

After the war finances were at a low ebb and dredging was seriously in arrears. The Government came to the aid of the Ports and Cork benefited considerably from this action. The city port was re-designed for accommodation of the war-developed "Liberty" and "Victory" ships, the latter being about 470-ft. long and drawing 27½-ft. loaded.

A length of 850-ft. of Anderson's and the North Custom House Quay was deepened to 25-ft. L.W.O.S.T. by driving a line of steel sheet piling in front of it, anchoring the piling to groups of piles well placed, and capping the new wall with a reinforced concrete coping (Fig. 6). The South Jetties was again replaced by a concrete piled structure having a berth depth of 30-ft. The railway sidings were transferred to ship side. Crane track was incorporated and bollards were placed at the wharf edge. Pneumatic Grain Plant has been installed on the new wharf which has just been completed (Fig. 7).

A third major work of reconstruction is to commence this year at the north side of the river where a frontage of 1,185-ft. of wharf and wall is to be reconstructed for 30-ft. low water.

Starting at the Fishguard Wharf the western section (Fig. 8), 645-ft. long is to consist of concrete piled wharf outside a steel sheet piled wall tied to a continuous block anchorage. The wharf will be 12½-ft. wide from front to sheet piling, the slab and beams will project landward of the sheeting a distance of 14½-ft. where a concrete pile will be driven under each transverse beam. The bays will be 11-ft. long. Crane track and shipside sidings will be provided. Eastward of the wharf a swinging basin is to be constructed by widening the river 40-ft. for a distance of 480-ft. The structure here will be a relieving platform 30-ft. wide, based 5½ ft. over low water. The platform will be carried on a line of steel sheet piles at the front and three rows of raking concrete piles. The retaining wall on the platform will be 13-ft. high with counterforts the full width of the platform every 12-ft. (Fig. 9). The platform will continue around the end return walls. Tenders have been invited for this work.

In 1938 the Commissioners had only the "Owenacurra" and "Grabwell" in commission as dredgers. The latter vessel, purchased in 1936, is a small (380 tons capacity) hopper dredger with one Priestman grab crane. A floating pump-ashore plant and four 300 ton dumb elevator barges were accordingly purchased in Holland in 1948. The pump-ashore plant "Montgomery" has a mud pump driven by a 420 h.p. diesel engine and a water pump of 250 h.p. It is provided with 2,000-ft. of 18-in. shore pipe. It is moored permanently at a jetty below Tivoli. For towing the barges a 220 h.p. tug, the "Richard Wallace," was purchased in England in 1948. These vessels with the "Loughmahon" dredger form the "Loughmahon" flotilla that does the major portion of dredging nowadays. The flotilla went into action early in 1949.

Anticipating greatly increased dredging output, the Tivoli Embankment was extended 2,700-ft. between July, 1948, and August, 1949. The reclamation was accelerated by construction of brushwood baffles between the embankment and the north shore. A contract for a further extension of 2,400-ft. has just been declared. Fig. 10 (see main plan) shows the reclamation area, an ideal industrial site flanked by the main Dublin-Cobh railway line and the

The Port of Cork—continued

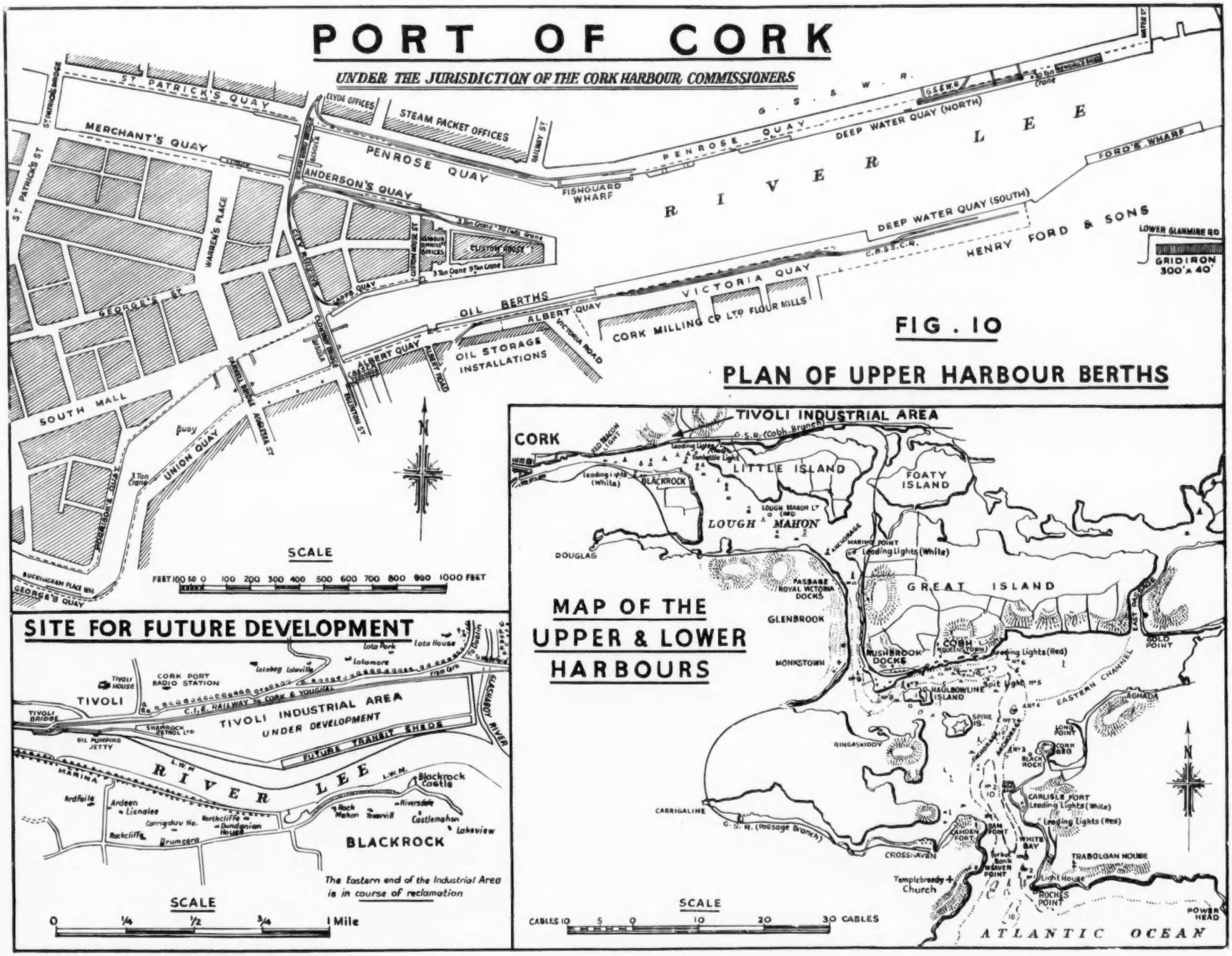


FIG. 10

PLAN OF UPPER HARBOUR BERTHS

The Port of Cork—continued

Dublin-Cork road on one side and by a river frontage that can at any time be deepened as much as necessary. Ships of 600-ft. length will be able to swing easily there.

As an ancillary service to dredging, echo-sounding was fitted up in a 28-ft. launch.

In 1949 the Commissioners purchased at a cost of £26,000 the 600 ton tug "Francis Hallinan" to help the larger ships up from Passage as necessary and for swinging at Cork Quays.

The Lower Harbour.

It is not possible in the scope of this article to deal with the Lower Harbour from Passage down to the sea beyond giving a few brief facts. The pilotage service is based on Cobh which is also the centre of the largest overseas tourist traffic in Ireland. In 1954 nearly 27,000 passengers landed from or embarked there. There were 177 liner calls that year. The tender service is also based on Cobh. The Whitegate-White Bay district near the harbour mouth (see Main Plan) has recently been selected as the site for an oil refinery opening up prospects of the establishment of subsidiary industries and much employment.

The ocean approach to the Lower Harbour, a wide bay over five miles across from Poer Head, on the east, to Cork Head on the west, is so sheltered that in reasonably fine weather the trans-Atlantic Liners can embark and disembark passengers there from the Commissioners' Tenders. The entrance to the Lower Harbour proper in the centre of this bay is through a passage about 3,000-ft. wide at the entrance, which is not obstructed by a bar, and consists of two short channels with a minimum depth of 38-ft. at L.W.O.S.T. in the eastern channel, and 42-ft. in the western channel. The channels are divided by a rock known as the Harbour Rock, the position of which is marked by lighted buoys. Leading Lights and marks enable either channel to be navigated in safety. After passing the Harbour Rock these two channels merge into one broad approach which, almost two miles inside the entrance, forms the trans-Atlantic Liner Anchorage of 4,000-ft. by 2,000-ft. with a minimum depth of 36-ft. at L.W.O.S.T. A short distance north of the Liner Anchorage the channel turns westward and shoals to 30-ft. at low water, but afterwards deepens to 60-ft. as far as Passage. At Cove the Harbour Commissioners own the Ballast Quay, depth 14-ft. at L.W.O.S.T., which is used for the discharge of coal and other goods, and the Deep Water Quay, depth 22-ft. L.W.O.S.T. This latter quay is adjacent to the Railway Station and here the tenders from the trans-Atlantic Liners berth to receive or discharge passengers and mails. Ships of 21-ft. draught can berth at this quay. Up-to-date passenger accommodation, customs facilities and reception rooms have recently been provided at the point of disembarkation.

Hydraulics Research

Report for 1955

The Report of the Hydraulics Research Board for 1955 was published last month by Her Majesty's Stationery Office for the Department of Scientific and Industrial Research, price 4s. (72 cents U.S.A.), by post 4s. 3d. The Report describes the work being carried out by the Hydraulics Research Station at Wallingford on problems in loose boundary hydraulics. This research includes investigations of coast erosion, of problems of siltation in the Thames and other estuaries, land reclamation schemes and flooding, and the study of waterways and harbours by means of tidal models.

The Main Hall of the Station came into use during the year making a floor space of 300-ft. by 200-ft. available for experimental work and models to investigate problems of flooding in the River Severn near Shrewsbury and in the tidal reaches of the River Trent have been constructed. The Report stresses the need for more space to carry out urgent background research into coast erosion.

Radio-Active Tracers Technique.

Experiments in the use of radioactive tracers to follow the movement of bed material under the combined influence of waves and coastal currents were carried out on the south coast and indicated that this method, which has already been used in the study of siltation in the Thames, is likely to be practical in the study of coastal currents and coast erosion. If this proves to be the case, a valuable new tool will be available for examining the casual relation between the movements of coastal material and wave and tide characteristics.

The Thames Barrage Project.

Experiments on behalf of the Thames Technical Panel which had been set up by the Ministry of Housing and Local Government were continued during the year, in connection with various types of surge-reducing barrages designed to protect London and its environs from storm surges and flooding of the kind that occurred in February, 1953. The Port of London Authority's Pilot Model of the Thames was used to investigate the effects, upstream and downstream, on the high water levels of a storm surge similar to that of 1953, of closing the gates of a surge-reducing barrage at different times in relation to the time of high water, and of the effect of different rates of closing the gates. The relative merits of different barrage sites were also studied. The results of the model experiments were used by the Panel in drafting their final report which has now been submitted to the Ministry of Housing and Local Government.

The Shrewsbury Flood Relief Scheme.

A model, 145-ft. in length, which reproduces about 24 miles of the River Severn near Shrewsbury, is being used to investigate the effects of the proposed flood relief scheme of the Severn River Board on the unimproved river downstream, with particular reference to the incidence of flooding and flood levels. A general survey of the stretch of river under investigation was carried out and yielded valuable information on bank flooding, the nature of the bed, islands, weirs and bridges. An alternative relief scheme which does not require alterations to the present river channel, but involves the utilisation as a flood spillway of a short length of derelict canal and a low-lying land area which may at one time have been part of the river's course, is also being studied.

Coast Erosion.

The Station has continued to collect data concerned with the causes of coast erosion and methods of prevention. The staff visited many parts of the coast and discussed local erosion problems with authorities on the spot. Most of the east and south coasts of England have now been inspected, photographed and documented in considerable detail and the major factors which appear to control conditions from Yorkshire to Devon have been outlined.

The work carried out by the survey teams on the length of coast between Bournemouth and Christchurch has consisted of repeated surveys of the beaches and offshore zones in an attempt to determine how beaches in front of different types of sea defence works behave when subjected to similar waves and tides. A basic model of a coastal beach is being used to study the efficiency of various types of beach defence structure.

Land Reclamation.

Survey Work on a small portion of River Wyre Estuary has been completed, detailed observations having been made of the periodic formation and erosion of central and marginal banks. The investigation has been of particular value for the light it has thrown on the effect of building training walls for the stabilisation of fluctuating channels in estuaries, and in indicating the danger of interfering with the natural processes of erosion. It has also shown that the problem of hastening accretion for land reclamation is primarily a hydraulic one, involving the prevention or reduction of erosional processes and the encouragement of deposition from suspension.

The lessons learned from the Wyre investigation are being applied to the reclamation of certain areas of the Wash.

Hydraulics Research—continued

Gallions Lower Entrance Lock.

A model investigation was made of scour at the riverside edge of the apron at the Gallions Lower Entrance Lock in the Port of London. In order to investigate the behaviour of the existing sluices a geometrically similar 1/20 scale model was built at Victoria Dock; the experiments showed that relatively small alterations to the sluice outlets would greatly reduce the tendency for scour to occur in front of the concrete apron, and would completely prevent undermining of the apron. The alterations are being made to the prototype structure.

Dymchurch Sea Wall.

A model investigation was carried out on behalf of the Kent River Board into a suitable design for the length of the old Dymchurch Sea Wall that is about to be modified and repaired. The modifications to be carried out had to be of a kind that could be achieved by adding material to the existing wall, and the revised design was to give improved resistance to overtopping and, if possible, to reduce wave attack on the upper slope, which was less badly worn than the lower slope. A typical section of the existing wall, and of the modified design, was tested on a scale model and it was found that the addition of a 3.3-ft. layer to the lower slope, tapering to nothing at the upper and lower ends of the slope, was effective in reducing wave attack on the upper slope because it compelled all waves, even at very high tide levels, to break before they reached it. It also had a slightly beneficial effect in reducing overtopping by compelling the waves to break further away from the crest of the wall. The erection of a 4-ft. wall at the rear of the crest was found to be most effective in preventing overtopping.

WORK FOR OVERSEAS PROJECTS

Port of Tema.

Two model investigations have been undertaken on behalf of a firm of consulting engineers to study various aspects of the design of a new harbour to be built at Tema on the Gold Coast. The first model was of the two-dimensional type and consisted of cross sections of several designs of breakwater set on a sloping bed that represented the sea-bed offshore from Tema. The experiments were carried out to determine satisfactory profiles for various lengths of the breakwaters. The second model is three-dimensional and reproduces to a smaller scale the whole harbour and its environs. It is being used to determine the best layout for the breakwaters and quays in order to minimise the disturbance caused by waves to shipping.

In the first model ten different profiles for the breakwaters were investigated, some of them in more than one depth of water. The principal objects were to measure the height of the smallest wave that would cause damage to the breakwaters and to determine the amount of spray or green water that would pass over the tops of the breakwaters during storms. Waves of two periods and many different heights were used in the experiments and it was found that the shorter waves, of 9-sec. period, were more likely to damage the heavily armoured seaward face of the breakwaters. The longer waves, of 18-sec. period, were more likely to overtop the breakwaters; in addition they sometimes caused damage to the lightly armoured inner face of the breakwaters. It was found early in the investigation that the main armour rock, consisting of natural rocks between 5 and 10 tons in weight, was stable on a slope of 1 in 2 when attacked by waves of anything up to 16-ft. in height. This feature of the design having been settled, the experiments were then devoted to finding an economical design that would minimise overtopping by high waves of 18-sec. period. The amount of overtopping that took place when 18-sec. waves 16-ft. high attacked a simple rubber mound was considered to be tolerable if the profile was used only for the outer length of the main breakwater, remote from any port installations. A number of designs were investigated for the inner lengths of the main breakwater where no overtopping whatever could be allowed and during this investigation it was found that to provide equal protection against overtoping from unbroken waves, a rubble mound breakwater needs to be higher (above still water level) in shallow water than in deep water.

The principle problem to be studied in the three-dimensional harbour model concerns the design of the harbour entrance. The breakwaters in this region will be situated in 45-ft. of water and may cost between £200 and £300 per foot run. It is therefore economically important that the breakwaters should not be unnecessarily long and that the length decided upon is efficiently employed. The second object of the investigation is to ensure that the quays are sited in places of small wave action and in such a way that they do not by their presence increase the local wave action. The model is also being used to supplement the information on topping gained from the first model. Tema Harbour is to be built in three stages. The first stage will be the construction of one finger berth, the second will involve the construction of two more finger berths, one on either side of the first, and the possible third stage, not to be reached for many years, is the reclamation of land along the present beach for the construction of new berths. All three stages of development are to be tested.

The Karnafuli River.

An investigation of the Karnafuli River and Port of Chittagong is being carried out on behalf of the Government of Pakistan, under the auspices of the Technical Co-operation Scheme of the Colombo Plan. Chittagong lies on the right bank of the Karnafuli, some ten miles above its outfall into the Bay of Bengal, and is being developed as the chief port of East Pakistan. Conditions in the river must be improved if the port is to expand and to offer suitable facilities for world shipping.

There are two major problems for investigation: firstly, in the tidal reaches at and immediately above Chittagong, the present rapid fluctuation of the channel meanders must be stopped and a stable channel of suitable depth provided alongside the jetties; and secondly, adequate depths must be established and economically maintained at the entrance bars and in the approach channel to the port. The considerable effects of a large new hydro-electric scheme, being constructed on the Karnafuli about 30 miles upstream of Chittagong, will also have to be examined. These problems will be studied in a large mobile-bed model of about 20 miles of the Karnafuli River from the sea to a point about 2 miles upstream of its junction with the Halda River. A 5-mile length of the coastline will be included at the seaward end. Construction of the model is under way in the Main Hall and at the same time, an analysis is being made of data from Chittagong on bed levels, tides, discharges, currents, salinities, suspended loads and bed materials.

The investigation has been divided into two stages. Stage I will be concerned with the stabilisation of the channel meanders, and for experiments in this connection the upper part of the model, as far seaward as a point 4 miles above the outfall of the Karnafuli, is being constructed first. In Stage II, the model will be completed to the seaward limit and will be used for experiments aimed at increasing the depth of water on the entrance bars. This two-stage scheme will enable one major part of the investigation to progress while the design, construction and testing of the complex apparatus necessary to reproduce the combined effects of tides and coastal currents at the outfall is carried out.

Tainter Gate Intake Model.

A model investigation concerned with the hydro-electric development of the Lower Caroni River in Venezuela has been conducted for a firm of consulting engineers. The scheme includes a bank of six intakes to Francis turbines, and experiments were carried out with the object of checking the general behaviour of the flow and the losses of head through the intake for the maximum working discharge over the full range of anticipated water surface levels; emergency closures of the Tainter gate and the turbine guide vanes were simulated in the model both for the maximum working discharge and for the maximum discharge which might occur in the event of the load suddenly coming off and the turbines "running away." Losses across the trashrack were found to agree well with calculations based on straightforward assumptions. The general behaviour was found to be good, the flow lines following the boundary with no eddying or separation. The upstream surge resulting from an emergency closure of the Tainter gate reached a maximum of 1.74 metres (prototype) for the runaway discharge combined with the lowest anticipated water surface level.

The Torsion-Resisting Steel Dolphin

Absorbing Impact Stresses

By HUGO MINNICH

A. General Features

The magnitude of the stresses, the amount of energy that can be absorbed, and the manner in which the forces are transmitted to the earth under central or eccentric impact are the technical criteria for the efficiency of a dolphin.

Analysis of the dolphin for central impact alone does not reveal its true efficiency. Central impact is to be regarded merely as a limiting case of eccentric impact. In manoeuvring the vessel alongside, the helmsman is not in the least concerned whether he hits the dolphin centrally or eccentrically. From his point of view, the whole dolphin is available for bringing his vessel alongside. The probability of the dolphins being hit centrally by the vessel is therefore very small and merely represents an exceptional case. Logically speaking, eccentric impact is thus by far the most common case. For the safe and economical design of a dolphin it is therefore imperative to analyse it for eccentric impact. This view has latterly come to be generally adopted in Germany since the early part of 1951, when the author's brother first published his views on the subject and drew attention to these conditions.

The older systems of dolphin—in particular those with parallel piles, referred to in Germany as " bundle " type dolphins—were designed only for central impact. These dolphins are characterised by the fact that the horizontal bracing is connected to the individual piles by means of loose or hinged joints. Under eccentric impact the amount of energy that such a " bundle " type dolphin is capable of absorbing is generally only about half of what it can take up under central impact. In view of the frequent occurrence of eccentric impact, this considerable reduction in energy absorption makes this type of dolphin an uneconomical system. This uneconomical performance was pointed out by the author's brother, who, with a view to avoiding the great reduction in energy absorption, was the first in Germany to develop the dolphin provided with torsional bracing and to demonstrate its effectiveness and indicate the basic mathematical relationships for the analysis of its behaviour.

The torsional bracing is connected to the individual piles by means of torsion-resisting joints, the piles acting as cantilevers. Thanks to this torsional bracing, the reduction in energy absorbing capacity under eccentric impact is practically eliminated. It is only then that the steel dolphin really becomes an economical system.

After the principle of torsional bracing evolved by the author's brother and the method of construction developed by him had proved their worth by authoritative tests, torsional bracing was soon adopted in a large proportion of the dolphins as nowadays constructed.

Patent applications for the " Willy Minnich " type of dolphin with torsional bracing have been filed in Germany and in some other countries. The largest dolphins of this type that have hitherto been built were constructed for the Shell Company of New Guinea, in 1953, in accordance with designs prepared by Willy Minnich in co-operation with Hüttenwerke Iselde-Pein A.G., Peine, Western Germany. Although the soil conditions were unfavourable, these dolphins provided with torsional bracing have proved highly satisfactory.*

In the present article it will not be possible to do more than briefly touch upon the theoretical side of the problem of the torsion-resisting dolphin. Some fundamental formulae will be indicated. The author will publish shortly a comprehensive theoretical treatise on the subject in Germany.

First of all, the essential difference between the dolphin with loose or pin-jointed bracing (" bundle " type dolphin) and the dolphin according to the " Willy Minnich " system (i.e., provided with torsional bracing) will be explained. For the purpose of this discussion it will be assumed that in all cases the force due to the eccentric impact blow delivered by the vessel is located in the plane of the pin-jointed bracing or in that or the torsional bracing respectively.

*Reference : " De Ingenieur ", 1954 (The Hague), No. 32, page B 131.

1. Dolphin with pin-jointed bracing.

Fig. 1 shows a diagrammatic view in plan of a dolphin consisting of the bracing and the piles with pin-jointed connections. The external force P is applied at an arbitrary distance e = r and produces an external torsional moment M_T = P.r. in relation to the axis of torsion of the dolphin. According to the rules of statics, the most

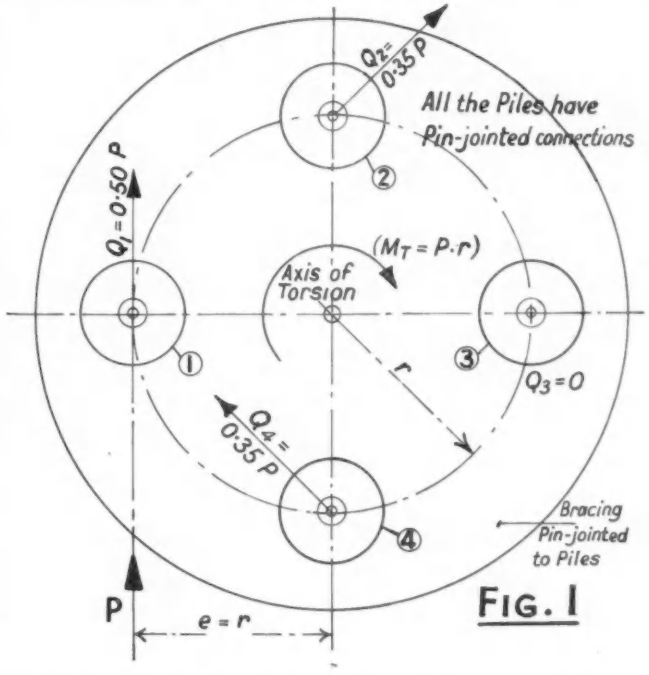


FIG. 1

heavily loaded pile No. 1 will then be subjected to a load equal to

$$Q_1 = 0.50\ P$$

and the least heavily loaded pile No. 3 will be subjected to :

$$Q_3 = 0$$

Piles No. 2 and 4 will have loads :

$$Q_2 = Q_4 = 0.35\ P$$

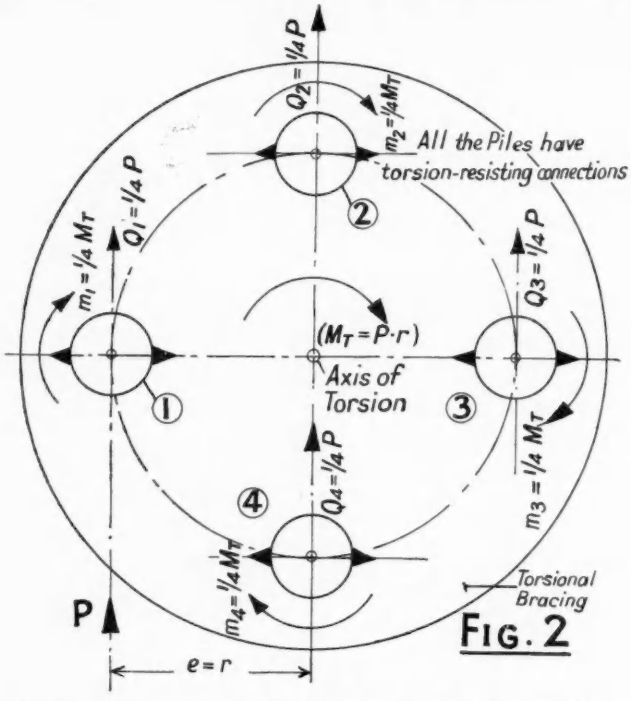
Piles Nos. 1—4 are thus subjected to loads differing in respect of magnitude and direction.

This unsatisfactory utilisation of the strength properties of the piles cannot be avoided by choosing different cross-sections for the piles, for the distribution of the external forces over the piles is a stiffness problem not a strength problem. The pile forces, differing in magnitude and direction, set up intersecting fields of force in the ground and cause unequal loading of the foundation soil.

2. Dolphin with torsional bracing.

In Fig. 2 the torsion-resisting connection of the piles to the torsional bracing is indicated diagrammatically by the black triangles. The torsion-resisting principle embodied in the Willy Minnich idea is that when the eccentric blow causes the torsional bracing to twist, all the piles with their torsion-resisting connections must rotate through the same angle as that through which the bracing rotates. In relation to its cross section held firmly in the ground, each pile is thus twisted by the same angular amount as the bracing. In the piles this causes torsional moments corresponding to the angle o

The Torsion-Resisting Steel Dolphin—continued



rotation. These torsional moments are in equilibrium with the external moment of torsion. From the relationship for the distribution of the external torsional moment and the internal forces of the piles (which relationship is given below) it follows that, in the case of torsion-resisting connection of the piles, the whole of the external moment of torsion M_T may in general be assumed—with sufficient accuracy for practical purposes—to be distributed over the piles as individual torsional moments m_t. In virtue of this principle, the piles each have the same loading, viz.:

$$Q = \tfrac{1}{4} P$$
$$m_t = \tfrac{1}{4} M_T$$

Superposition of these shear forces and bending moments only slightly reduces the permissible flexural stress, as is apparent from the stress relationship : $\sigma_v = \sqrt{\sigma^2 + 3\tau^2}$

In the above equation,* σ denotes the flexural stress due to the external load P, and τ is the torsional stress due to the external moment of torsion M_T. The equivalent stress is σ_v. Furthermore, σ_F denotes the yield stress, and σ_{perm} the permissible stress in the steel.

Then $\sigma_{perm} = \sigma_F = \sigma_V$

The strength properties of all the piles are equally utilised. Thanks to this effect of the torsional bracing, the dolphin will be just as efficient under eccentric as under central impact. Only thus does the steel dolphin really become an economical proposition. Owing to the uniform loading of the piles in respect of magnitude and direction of the loads, the foundation soil is also loaded more uniformly. The magnitude of the torsional moments to be transferred to the soil should be governed by available experience.

As the strain energy of an individual pile of the dolphin, for diminishing values of the deflection, is reduced in proportion to the square of the deflection, the dolphin undergoes its greatest loss of energy during the early part of its torsional rotation. A rotation of only 5–7° may already reduce the energy by one-third. The torsional bracing must therefore be so connected as to give the least possible amount of " play " or latitude. To assist the reader in arriving at a fuller understanding of this torsion principle, the following supplementary treatment of the problem is given, based on Fig. 3.

In the unloaded condition, pile No. 1, which is provided with a torsion-resisting connection, is in position 1. Under the action of an external moment of torsion M_T, due to an eccentric blow, the bracing rotates through an angle α. Owing to the torsion-resisting connection of pile No. 1, relative rotation of pile No. 1 with respect to the bracing is not possible, and so this pile will pass from position 1 to position 1^1. The pile will, at the same time, undergo a twisting rotation through an angle $\varkappa$ relative to its cross section fixed firmly in the ground. In addition to the torsional moment m_t, a shear force T_1 is simultaneously set up in consequence of the deflection $\delta_1 = r_1 \alpha$ due to this forced rotation α of pile No. 1.

In the initial unloaded) condition, pile No. 2 (Fig. 3), which is pin-jointed, is in position II. Owing to rotation of the bracing through an angle $\varkappa$, this pile will be displaced to position II^1, without undergoing any rotation about its own centre line. The axes a–a and b–b of pile No. 2 remain parallel before and after the rotation of the dolphin. The pin-jointed pile No. 2 thus takes up no torsional moment (i.e. $m_t = 0$) ; the deflection $\delta_2 = r_2 \alpha$ of this pile merely produces the shear force T_2.

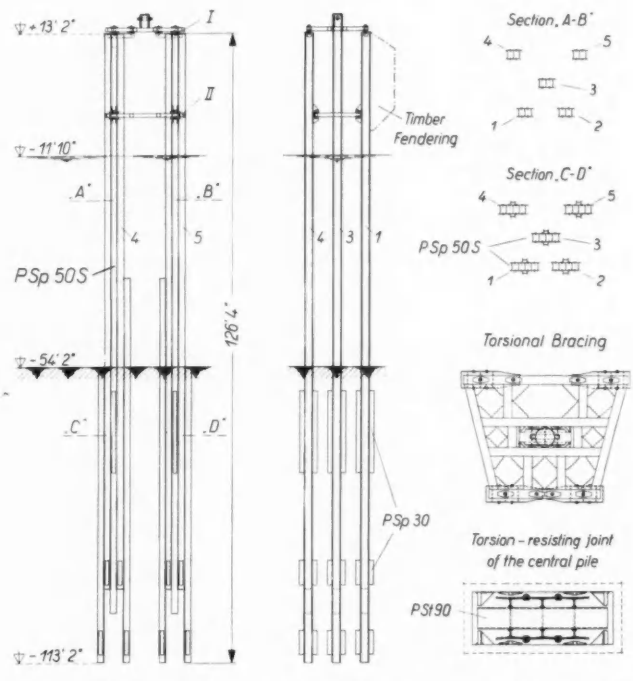
For simplicity, only the equations for piles of circular cross section for torsion-resisting dolphins will be given here. These equations are subject to the following assumptions :

1. The external moment of torsion M_T acts in the plane of the torsional bracing.
2. The angle of rotation $\varkappa$ is so small that the shear forces T act in the planes of the deflections δ (Fig. 3).
3. The equivalent length H_0 of the pile* is the same for bending and for torsional rotation.
4. The equivalent length H_0 is the same for all the piles of a dolphin.

Let : v = the total number of piles of a dolphin ;
w = the number of piles with torsion-resisting connections
I = the moment of inertia about a diametral axis.

Then, the condition for equilibrium about the axis of torsion will be :

$$M_T = \sum^{w} m_t + \sum^{v} (T.r)$$



Torsion-resisting Dolphin for the Pipe Line Jetty on the Muturi River (Dutch New Guinea) constructed of Peine Box Piling. Cross Sections and Details of Torsional Bracing.

* *Translator's note :*

According to Huber & Hencky's theory of failure the " ideal " or " equivalent " criterion stress σ_v for a case of combined normal stress (σ) and shear stress (τ) is expressed by the relationship :

$$\sigma_v = \sqrt{\sigma^2 + 3\tau^2}$$

*$H_0 = h + 0.78\ t_0$ according to Müller, " HANSA ", 1953, page 1988. Penetration " t_0 " as given by Blum, " Die Bautechnik ", 1932, No. 5.

The Torsion-Resisting Steel Dolphin—continued

The relationship for the distribution of the external torsional moment and the internal forces for pile No. 1, arbitrarily chosen as reference pile, will be :

$$m_{t(1)} = \frac{I_1 \cdot H_0^2}{H_0^2 \overset{w}{\Sigma} I + 3.90 \overset{v}{\Sigma} (I.r^2)} \cdot M_T$$

$$T_1 = 3.90 \frac{r_1}{H_0^2} \cdot m_t(1)$$

For pile No. i :

$$m_t(i) = m_t(1) \frac{Ii}{I_1}$$

$$T_i = T_1 \frac{I_i \cdot r_i}{I_1 \cdot r_1}$$

This distribution relationship, in combination with the stress relationship $\sigma_v = \sqrt{(\sigma^2 + 3\tau^2)}$, clearly demonstrates the qualitative and quantitative superiority of torsional bracing. As has already been stated, it follows, with sufficient accuracy for practical purposes, that in general the whole of the external torsional moment is taken up by the piles loaded in torsion.

As already stated above, the economical design of a dolphin is not merely a strength problem but is also, as the distribution relationship shows, a stiffness problem. The most economical dolphin is obtained if all the piles have torsion-resisting connections. Constructional considerations may also play a part in determining the number of piles to be so connected, however. Thus, in the first torsion-resisting " bundle " type dolphins, which were installed at the port of Lübeck in 1951, not all the piles were provided with torsion-resisting connections. By connecting several piles, or all the piles, in such a manner as to be capable of resisting torsion, it will at the same time be ensured that no excessively large concentrations of torsional moment are transmitted to the soil. Consequently, the soil will be loaded more uniformly within the region of influence of the dolphin.

The author has also derived equations for determining the position of the axis of torsion which has already been referred to in this article. The centroidal axis of a dolphin has, in the past, been assumed to coincide with the axis of torsion. This latter axis is characterised by the fact that a force applied so as to intersect it does not produce a torsional moment in the dolphin and thus causes no rotation thereof.

The position of the axis of torsion is determined by the distances x_0 and y_0 to the axes of an arbitrarily chosen system of co-ordinates.

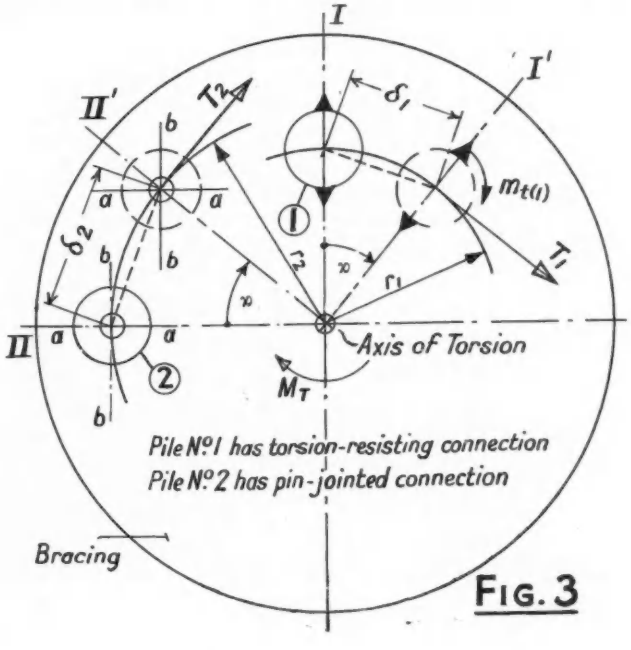


FIG. 3

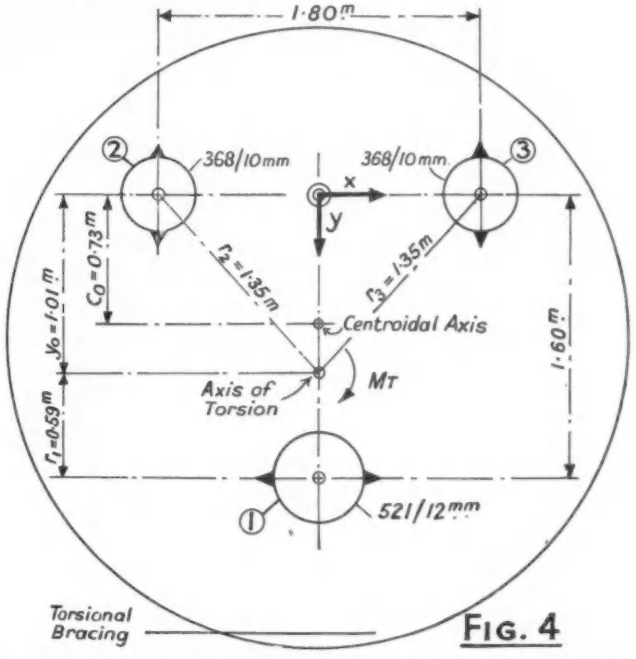


FIG. 4

The co-ordinates x and y denote the distances of the piles. All radii perpendicuar to the T-forces intersect on the axis of torsion. For the dolphin with piles of circular cross-section the following relationships are obtained :

$$X_0 = \frac{\overset{v}{\Sigma} (I \cdot x)}{\overset{v}{\Sigma} I}$$

$$Y_0 = \frac{\overset{v}{\Sigma} (I. y)}{\overset{v}{\Sigma} I}$$

The position of the axis of torsion in the case of piles of circular cross-section can therefore be defined as the centroid of the moments of inertia. If the piles all have equal moments of inertia, then the position of the axis of torsion will coincide with that of the centre of gravity of the system.

The strain energy of a dolphin is :

$$A = \tfrac{1}{2} P\delta + \tfrac{1}{2} M_T \cdot \varkappa$$

where δ represents the deflection due to the external load P and $\varkappa$ denotes the rotation of the dolphin due to the external torsional moment M_T.

A numerical example will serve to illustrate the essentials of the application of the distribution relationship and confirm that the external torsional moment will in general be amost entirely transmitted to the piles as individual torsional moments.

In Fig. 4 a dolphin with three piles is shown in plan. The external torsional moment M_T in the plane of the bracing acts about the axis of torsion, the position of which still has to be determined. The equivalent pile length is :

$H_0 = 10.0$ m.

The cross-sections of the piles are as follows :

(F denotes the cross-sectional area).

Pile No. 1 : 521 × 12 mm.
$F_1 = 192$ cm²
$I = 622 \times 10^{-6}$ m⁴

Piles No. 2 and 3 : 368 × 10 mm.
$F_2 = F_3 = 112.5$ cm²
$I^2 = I_3 = 180 \times 10^{-6}$ m⁴.

Position of the axis of torsion :

From considerations of symmetry : $x_0 = 0$

Furthermore : $\Sigma I = (2 \times 180 + 622)\ 10^{-6} = 982 \times 10^{-6}$ m⁴

In relation to axis y–y in Fig. 4 :

$$\Sigma (I \cdot y) = 622 \times 10^{-6} \times 1.6 = 995 \times 10^{-6} \text{ m}^5$$

The position of the axis of torsion is therefore :

The Torsion-Resisting Steel Dolphin—continued

$$y_0 = \frac{999}{98^2} = 1.01 \text{ m}$$

Position of the centroidal axis :

$$\Sigma F = 2 \times 112.5 + 192 = 417 \text{ cm}^2$$
$$\Sigma (F.x) = 192 \times 1.6 = 307 \text{ cm}^3$$

Hence the position of the centroidal axis is :

$$C_0 = \frac{307}{417} = 0.73 \text{ m}$$

It thus differs considerably from the position of the axis of torsion.

Application of the distribution relationship :

All three piles are provided with torsion-resisting connections, and therefore :

$$v = w = 3$$

Then (as before) : $\Sigma I = 982 \times 10^{-6} \text{ m}^4$

and $\Sigma (I.r^2) = (622 \times 0.59^2 + 2 \times 180 \times 135^2)\, 10^{-6}$
$= 872 \times 10^{-6} \text{ m}^6$

The torsional moment of pile No. 1 is therefore :

$$m_1 = \frac{622 \times 10.0^2}{10.0^2 \times 982 + 3.90 \times 872} \cdot M_T = 0.62\, M_T$$

and the shear force is :

$$T_1 = \frac{0.62\, M_T\ 3.90 \times 0.59}{10.0^2} = 0.014\, M_T$$

Furthermore :

$$m_2 = m_3 = 0.62\, M_T \frac{180}{622} = 0.18\, M_T$$

and $$T_2 = T_3 = 0.014\, M_T \cdot \frac{180 \times 1.35}{622 \times 0.59} = 0.009\, M_T$$

A check is provided by the following equation :

$M_T = (0.62 + 2 \times 0.18)\, M_T + (0.014 \times 0.59 + 2 \times 0.009 \times 1.35)\, M_T = 1.0 M_T$.

m_1 can be calculated by means of the following approximate formula :

$$m_1 = \frac{I_1}{\Sigma I} \cdot M_T = \frac{622}{982} \cdot M_T = 0.634\, M_T$$

and then : $$m_2 = m_3 = \frac{180}{622} \times 0.634\, M_T = 0.183\, M_T$$

$$m_t = (0.634 + 2 \times 0.183)\, M_T = 1.0\, M_T$$

As has been said, the discrepancies between the values of the torsional moments obtained from the more accurate distribution relationship and those from the approximate formula are therefore negligible.

APPENDIX

Derivation of Basic Formulae

The relationship between the external torsional moment and the resulting internal forces and moments is derived from basic principles as follows :—

For a circular shaft of effective length H twisted through an angle $\varkappa$ by an applied moment m_t

$$\varkappa = \frac{m_t H}{NJ}$$ where N = modulus of rigidity, J = polar moment of inertia

$J = 2I$ (where I = diametric moment of inertia

$$N = \frac{E}{2(1+\upsilon)} = \frac{2}{5} E$$ (where E is Young's Modulus and υ is Poisson's ratio = (say) $\frac{1}{4}$)

$$\text{Hence } \varkappa = \frac{5\, m_t H}{4\, E.I}$$

$$\text{or } m_t = \frac{4\ E.I.\ \varkappa}{5.H.}$$

The sum of all such moments $\Sigma m_t = \frac{4E\varkappa}{5H} \Sigma I$ as E, $\varkappa$ and H will be constant for all piles.

One of the Torsion-resisting Dolphins for the Pipe Line Jetty on the Muturi River (Dutch New Guinea) constructed of Peine Box Piling.

Assuming that all piles, whether pin-jointed or jointed by a torsion-resisting connection to the torsional bracing, deflect as free-ended cantilevers of length H under an applied force T,

$$\text{thus the deflection } \delta = \frac{TH^3}{3EI}$$

From figure 3, it will be seen that the applied force T causes a moment T.r. about the axis of torsion, which will be termed m_f, and $\delta = r.\varkappa$ (for small values of $\varkappa$)

$$\text{Hence } r.\ \varkappa = \frac{m_f\ H^3}{3EIr}$$

$$\text{or } m_f = \frac{3EI\varkappa\ r^2}{H^3}$$

The sum of all such moments $\Sigma m_f = \frac{3E}{H^3} \Sigma\ I.r^2$ as E and A will be constant.

Now the total external moment M_T is equal to the sum of the internal moments.

$$\text{i.e. } M_T = \Sigma m_t + \Sigma m_f$$
$$= \frac{4E\varkappa}{5H} \cdot \Sigma I + \frac{3E\varkappa}{H^3} \Sigma I.r^2.$$

As M_T will be known, it is desirable to express m_t and T in terms of M_T

$$\frac{mt}{M_T} = \frac{\frac{4EI\ \varkappa}{5H}}{\frac{4E\ \varkappa}{5H} \cdot \Sigma I + \frac{3E\ \varkappa}{H^3} \Sigma\ I.r^2}$$

$$\therefore\ m_t = \frac{I.H^2}{H^2\ \Sigma\ I + 3.75\ \Sigma\ (I.r^2)} \times M_T \quad \ldots \quad \ldots \quad (1)$$

$$T = \frac{m_f}{r} = \frac{3EI\ \varkappa\ r^2}{H^3.r} = \frac{3EI\ \varkappa\ r}{H^3}$$

$$\therefore\ \frac{T}{m_t} = \frac{\frac{3EI\ \varkappa\ r}{H^3}}{\frac{4EI\ \varkappa}{5H}}$$

$$\text{i.e. } T = \frac{3.75\ r}{H^2} \times m_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

(N.B.—In this derivation the constant 3.75 has been obtained assuming a value of υ for steel as $\frac{1}{4}$. In the article a slightly different value of υ has been used giving a constant of 3.90).

The Transport of Maritime Cargo

Unit Loads v. Individual Packages

Study by the U.S. National Research Council.

EARLY in 1955, the Maritime Cargo Transportation Conference of the National Academy of Sciences—National Research Council, Washington, U.S.A., began a programme of study for the purpose of "providing guidance on means and techniques leading to improvement in the sea transportation of general cargo." Results of the initial study in this programme were published by the Council under the title "The s.s. Warrior." This book contained an analysis of one voyage of a general cargo vessel carrying a miscellaneous cargo from New York to Bremerhaven (Germany). An article on this publication appeared in the June, 1955, issue of this Journal.

The primary aim of the "Warrior" study was to find ways and means of turning ships round more quickly, an important need in all maritime countries. The M.C.T.C.'s second study (Publication No. 389, December, 1955) states the problem in the following specific terms: "to develop data to assist the Air Force in determining the relative desirability of transporting subsistence cargo from east United States depots to the North East Air Command by (1) the conventional loose-cargo system or by (2) unitising the cargo on pallets or in transporters. This includes the receipt and storage in the overseas military warehouse at Goose Bay, Labrador." This particular study is therefore intended to throw light on the general problem of whether it is quicker, cheaper and better to transport goods across land and sea (a) as individual packages (b) in transporters (containers) (Fig. 1) or (c) as palletised unit loads, either sheathed (Fig. 2) or unsheathed (Fig. 3). The transporters have lifting eyes on top and metal "battens" underneath and are thus capable of being handled by mobile crane and fork-lift truck.

As with the "Warrior," the study now under review is divided into "segments": (1) Depot (2) Rail (3) Receipt and transit store (4) Loading (5) Voyage (6) Discharge (7) Truck loading and movement from berth (8) Warehouse. The conclusions are in terms of (a) dollar costs, (b) man-power and (c) time expended.

Segment 1: The Depot.

This "segment" is of much importance since what happens at the outset has such a big effect upon subsequent handling and transporting speeds and costs. As th study states, "to present the whole picture it is necessary to go behind the actual depot operational data." For example, for satisfactory conveyance, it is deemed necessary that certain loose goods should be in "export pack" and not in "domestic pack"

The following description is given of the Depot processes. Upon receipt of shipments of the loose cargo incoming from suppliers, all items are immediately palletised for storage on 40-in. x 32-in. warehouse pallets.

Fig. 1. Removing loaded transporters from depot flat car.

When shipment orders are received by the depot the loaded pallets move directly from storage into the box car by fork-lift. Within the car, two labourers remove the cargo from the pallets and stow the packages.

Palletised shipments are prepared by glueing all cartons together on the pallet and then binding the whole load and pallet with steel strapping. Cardboard sheathing is used between cartons and strapping in certain circumstances. The pallet used for shipment from the depot is the 48-in. x 40-in. type, with fork-lift access on all four sides.

The process of unitising cargo in transporters is marked by multiple intra-depot movements of the transporters. Upon arrival at depot from shipper, the empty transporters are stored in an open area. When the warehouse is ready to load cargo, the transporters are placed on a depot flatcar by fork-lift. The flatcar is then placed at the warehouse loading dock with transporter doors facing the warehouse. The transporters are not removed from the car. The 40-in. x 32-in. pallet loads are then brought from storage by fork-lift and a crew of two men removes the cargo from the pallet and stows it in the transporters. Later, a heavy-duty fork-lift removes the transporters from the car and stows them in the open.

The dollar costs presented are based upon the following elements: Actual cost of labour and equipment operators for actual working time required to perform the functions involved; actual cost of all mechanical equipment used for the actual hours of employment, based upon depreciation, maintenance and fuel consumption; cost of all materials used, such as glue, strapping, sheathing, and blocking and bracing materials in cars; cost of documentation; cost of each 48-in. x 40-in. pallet shipped is included in depot costs at $2.75 per pallet. No depot overhead is included in the costing.

Comparative performances in the Depot segment were:—

System	Pkgs per LT	$ Cost per LT	$ Cost per MT	MH per LT	MH per MT	Hours Work per LT	Hours Work per MT	Net LT Loaded per Car
Conventional	49	0.645	0.493	0.236	0.181	0.072	0.055	31.9
Palletised (Not Sheathed)	48	6.99	5.09	0.99	0.72	0.30	0.22	39.0
Palletised (Sheathed)	48	10.47	7.63	1.35	0.98	0.37	0.27	39.0
Transporter	47	2.57	2.00	0.82	0.64	0.23	0.18	20.0

Segment 2: Domestic Movement.

This segment deals with the process of transporting subsistence from the New Cumberland General Depot until it becomes the responsibility of the New York Port of Embarkation. Only movement by rail is considered, since movement by road was negligible.

The railroads provide for the movement of freight to NYPE by either of two methods, at the same tariff:

1. The railcar can be delivered to the marshalling yard within NYPE. In this case, the responsibility and cost of discharging the car belong to the port.

2. The cargo may be transferred from rail car to lighter at the Jersey shore terminus of the railroad and the lighter towed to NYPE. In this case, the railroad must pay for the transfer to the lighter and for putting the cargo ashore from the lighter, stacked manhigh within 100-ft. of the lighter door. In actual practice, because NYPE wishes its cargo to be placed on the piers palletised and at selected spots, the port assists the railroad contractor with men and equipment. The latter (port men and port equipment) are included in Segment III and not in the present discussion.

The cost data on this segment, in terms of net long tons of cargo is given as: loose goods $1.74, palletised $0.79 and transported $0.95.

Transport of Maritime Cargo—continued

It is concluded that "(1) palletising results in a requirement for 20% fewer box cars than for loose cargo; (2) employing transporters results in a requirement of 60% more cars than loose cargo, (2) rail tariff is approximately 17% greater for transporter cargo than for loose or palletised."

Segment 3: Receipt and Intransit Storage.

This segment covers the cost of receiving goods by the three systems under study and carries the cargo to the point of rest in the "farm area" at the pier or in a transit shed. The goods were received by one of two means: in railcars direct, or in lighters. Each boxcar of loose cargo was discharged by a team composed of five longshoremen, one fork-lift operator and one checker. The longshoremen placed the bags and cartons on 48-in. x 40-in. pallets and a 4,000 lb. fork-lift truck picked up the loaded pallets and delivered them to a point of final rest in the transit shed.

Only two cars of palletised subsistence were received directly in the port and each was handled in a different manner. One of the cars was placed at Warehouse B which is equipped with depressed track. The gang consisted of two longshoremen, one fork-lift operator and one checker. The longshoremen opened the car door and then stood by while the 4,000 lb. fork-lift removed the palletised units and transferred them to point of final rest in the warehouse. The other car was discharged at Pier 3 by a gang of three longshoremen, two fork-lift operators using 4,000 lb. trucks and one checker. After the longshoremen opened the car door, one fork-lift delivered units to the car door and the other transported the units to point of final rest in the pier shed.

Two gondola cars with transporters were received at Pier No. 1. The gang consisted of two longshoremen, one checker and one crane operator. The mobile crane picked up each transporter and carried it to point of final rest. Longshoremen were used to hook and unhook the containers.

Study of this segment led to the conclusions that: (1) The cost to the port is 6 to 12 times greater for cargo discharged from railcars in the port than if the cargo is lightered in; (2) of lightered cargo, unitised is cheaper than loose but the cost to the port is very small in each case; (3) insufficient data were obtained to permit a conclusive comparison of the three systems where direct movement to the port in railcars was involved.

Segment 4: Loading.

The ships examined loaded at two piers. Both piers are served by rail spurs; three lines are depressed and run down the centre of the pier, and two flush spurs are located on each apron. The piers are covered by one-storey transit sheds. Apron width is 28-ft. The transit shed surface is concrete while the apron surface is wooden. The port facilities are modern and do not present any peculiarities of an abnormal nature.

The loose cargo consisted of subsistence items in cartons and other commodities of a comparable nature to those which were palletised or stored in containers. These items include cigarettes, paper products, candy, cigars, beer, cleaning compounds and bagged cement; the last was adjusted to obtain a figure comparable to the large quantities of bagged flour and sugar loaded in the transporters. All of the loose cargo was handled in the conventional fashion, that is, it was stored on stevedore pallets (4-ft. x 6-ft.) on the pier and moved during loading from its stored position to the hook by fork-lift truck. Two fork-lift trucks served each hook. The loaded pallet was burtoned by the 5-ton ship's booms to the compartment in which it was to be stowed. In the hold the packages, bags, cartons, etc., were removed manually from the pallet and hand-carried to the stowed position. On occasion, roller conveyors were used to assist the gang in the stowage process.

Palletised Goods. The cargo prepared in the port was glued and strapped on 48-in. x 40-in. two-way pallets which were not fitted with lifting bridle lips. All New Cumberland General Depot palletised units loaded in the port were glued and strapped on 48-in. x 40-in. four-way pallets which were fitted with bridle lips. As a result, some operational difficulties were experienced in handling the two-way unlipped pallets, and the stevedore used three methods to load these. In one case, two wire bridles were passed under the pallet load which was placed on two 4-in. x 4-in. pieces of dunnage by the fork-lift. On frequent occasions, two units, placed one on the other, were lifted to the hold in this fashion. This method, however, resulted in considerable damage to the underside of the pallet and was abandoned. Another method employed called for placing one or two palletised units on a stevedore pallet (4-ft. x 6-ft.) side-by-side and using the stevedore pallet bridle to burton the load to the hold. This decreased pallet damage, but the return of empty stevedore pallets to the apron reduced the effectiveness of the hook by increasing the hook cycle time. A third method was also tried but proved too unwieldy. In this method, two wire bridles were passed between the top and bottom boards of the two-way pallet. Only one uit at a time was lifted and considerable time was consumed on the apron in threading the ends of the bridles between the pallet boards and in the hold in snaking the wires from between the boards when the unit was set down.

The handling of the lipped (winged) pallet presented no problems in this regard and the desirability of using this type of pallet for ship loading is outstanding (Figs. 4 and 5).

Transporter Loading. All of the transporters examined were loaded with cargo in the port area. This cargo consisted of bagged flour, bagged sugar and packaged subsistence used as filler to obtain maximum space and weight utilisation of the transporter. The average gross weight per transporter was 4.61 long tons; gross measurement is 9.10 measurement tons. The net cargo weight averaged 3.89 long tons and measured 6.70 measurement tons; the average net cargo stowage factor was 69 cubic feet.

Transporters were moved from the port marshalling yard on Army flat cars, where they were stored prior to loading to the ship, to the apron spurs alongside the ship. The cars were placed so that they could be moved by a pier tractor to put the transporters in the way of the ship's gear. Two slingers standing on the flat car attached the four-hook transporter bridle and the transporter was burtoned by the ship's five-ton booms into the compartment in which it was to be stowed. Two methods of stowage in the hold were employed. One, which obtained while transporters were being stowed on the tank tops or compartment deck, employed two pieces of MHE; a 6,000 lb. fork-lift truck lifted one end of the transporter and a pusher truck supplied the motive power to skid the transporter to its stowed position in the hold by pushing behind the fork-lift truck. In most cases, the light fork-lift truck rested only on its two front wheels while stowing and would have been unable to propel the heavy transporter.

By the other method, the MHE was removed from the ship and transporters were snaked two at a time into the wings abreast of the hatch square and into the ends of the hatch. In the square, transporters were swung into stowed position by ship's gear and manual labour.

It must be stated that this section on loading is a book in itself and it is difficult to do justice to it by quoting extracts. The con-

Fig. 2. Stencilling strapped and sheathed load.

Transport of Maritime Cargo—continued

Fig. 3. A strapped load of export packs; no sheathing required.

clusions and recommendations, therefore, are given in full. They are:—

Conclusions.

1. Cargo shipped in transporters is loaded with the least expenditure of dollars, manpower and ship time.
2. The stowage of palletised cargo, as performed, presented no advantage over the conventional system, but economic and operational advantages do appear when palletised goods are handled to the maximum by mechanical means.
3. The actual manpower investment in the stowage of transporters and palletised units exceeded the requirement for this function when materials handling equipment is employed. Manpower can be reduced and will yield savings in time and dollars.
4. The summary of actual performance is not a valid basis for decision as to whether the palletised system does or does not present advantages over the conventional system. The inconsistencies in operational procedures observed in handling palletised units have reduced the performance average of palletised cargo. The instances wherein optimum performance were observed were too small to weight the averages in favour of unitisation.

Recommendations.

1. That transporters be employed in the shipment of export subsistence cargo whenever practicable.
2. That transporters and palletised units be planned for vessel stowage in such fashion as will permit maximum use of materials handling equipment.
3. That manpower used in the stowage of transporters and palletised units be reduced to the level actually required when stowage is accomplished by materials handling equipment.

Segment 5: The Voyage.

In considering the voyage, account has been taken of the cost of the time the ship was on the berth for loading and discharging, as well as the cost of the time at sea. The matters examined in this segment are (1) the cost (of each of the three systems), (2) the use made of the carrying capacity of the vessel, (3) time and (4) manpower. It is interesting to note that the comparative tariff rates were, per measurement ton, loose goods $8.10; palletised $8.95; transporter $11.00. A table giving the comparison of ship costs for the three systems reads thus:

System (1) vs. System (2)	System (1) Cheaper	Difference less than 5%	System (2) Cheaper
Transporter	0 to 5-1/2 days	5-1/2 to 8 days	Over 8 days
vs. Loose	0 to 2,000 miles	2,000 to 2,900 miles	Over 2,900 miles
Pallets v.	0 to 2-1/2 days	2-1/2 to 7 days	Over 7 days
Loose	0 to 900 miles	900 to 2,500 miles	Over 2,500 miles
Transporter	0 to 5 days	5 to 14 days	Over 14 days
vs. Pallets	0 to 1,800 miles	1,800 to 5,000 miles	Over 5,000 miles

In drawing conclusions in the voyage segment, account has been taken, of course, of whether transporters were going to be returned empty or loaded. Ship design is also mentioned. The conclusions are:—

1. In the voyage of a conventional ship from Norfolk to Goose Bay, there is no substantial difference among the three systems in dollar or manpower cost per net MT. A slight advantage in each cost area accrues, however, to the transporter unless it returns empty to the U.S., in which case transporters become the most expensive.
2. In per diem capability to deliver net cargo tonnage on a conventional ship, transporters are appreciably superior to the other two systems; pallets are very slightly superior to conventional.
3. If a ship is designed with deck heights suitable to the economic stowage of unitised cargoes, then the transporter will give the best performance both in capability to deliver net MT of subsistence and in cost per net MT of cargo delivered. Again, however, if transporter is returned empty, cost per net MT will be the highest. The next best performance in both delivery-per-voyage day and cost-per-MT will be that of palletisation, and the least efficient will be conventional.

Segment 6: Discharge.

Those engaged in the port industry will find the discussion and data in segments 4 and 6 the most interesting part of the study. Fig. 6 shows the actual discharging berth at the Canadian-owned port of Goose Bay, Labrador.

The port is a quay-type installation with a concrete wharf 900-ft. long and more than 30-ft. wide which can accommodate nine hatches of the Liberty type vessels. The depth of the water alongside is 22-ft.

There are four transit sheds at the port, one of such has been set aside solely for the use of the Canadian government. These sheds are mainly used for the storage of export cargo.

The port is located approximately five miles from the Air Base. All cargo moves to and from the base by truck and, with the exception of about 0.8 miles, the road is well surfaced.

Equipment. Fork-lift equipment is available for the movement of cargo from the apron to trucks and for use aboard ship. These are for the most part 2,000 lb. fork-lifts with hard tyres. There were only two 15,000 lb. fork-lifts with pneumatic tyres available for handling transporters. One of these was inoperative for most of the time. All conventional cargo is removed from the hold of the ship on pallet boards with standard stevedore gear.

Time. Delays induced by numerous gear failures, rain and meal hours were excluded from operating time, as also was time expended in rigging, opening and closing of hatches, dunnage removal, gear changes and other housekeeping functions.

Cost. All labour performed in the discharge operation was by Army stevedore personnel for whom it was impossible to develop precise cost data. Since labour represents the largest single element of cost in stevedoring (approximately 70 per cent.), it was decided to cost the discharge operation on the basis of actual cost of labour and mechanical equipment that would have applied if the vessel had been discharged at Hampton Roads, Virginia. Equipment costs are based on Army fork-lift rental rates to a stevedore contractor.

Stevedore methods changed frequently. For example, fork-lifts were occasionally used underdeck to move unitised cargo; both heavy lift and 5-ton booms were used to discharge transporters; in some instances cargo was discharged directly from ship to truck while in other instances cargo was dropped on the apron and then loaded aboard trucks by fork-lift; gang sizes varied from draft to draft; labour performance varied constantly and work was performed on a day and night shift basis.

Manpower. The authorised army longshore ship hatch platoon used to discharge vessels is: 1 hatch foreman, 1 assistant hatch foreman, 1 signalman, 2 winchmen, 8 holdmen, 2 hookmen (apron), and 2 checkers, making a total of 17.

In actual practice the stevedore gang varied considerably from ship to ship and hatch to hatch. In some instances as few as three holdmen were noted and in other cases as many as 10. On occasion, the hatch foreman or the assistant hatch foreman were observed in the hold assisting the assigned holdmen. In those in-

Transport of Maritime Cargo—continued

stances where the heavy lift was used to discharge containers, three additional winch operators were required. The two checkers were not included in developing manhour data.

Description of Discharge Process (from two vessels).

Bagged Goods. A small percentage of the cement aboard the s.s. "Wellandoc" was discharged by the ship's steam winches. These proved inadequate and 5-ton crawler cranes were brought alongside the vessel to complete the discharge. Pallet loads were made up in the hold and discharged directly onto truck trailers placed under the hook.

The cement aboard the s.s. "Westport" was discharged with burtoned 5-ton booms powered by steam winches. Pallet loads were made up in the lower hold of the No. 3 hatch and deposited on the apron. 2,000 lb. hard tyre fork-lifts were used on the apron to load the pallets onto truck trailers which were brought alongside the working hatch.

Cartons. Pallet loads were made-up in the hold and discharged by burtoned 5-ton booms. Drafts were deposited on the apron and moved by fork-lift to truck trailers where the pallet load was broken and the cargo loose-stowed on the truck by shore platoons of four to six men.

The palletised cargo sample consists entirely of cartons of subsistence items glued and strapped on standard 48-in. x 40-in. pallets. Both two-way and four-way pallets were used, some of which were fitted with bridle lips. A sample of 487 units was developed with a weight of 440 long tons and cube of 680 measurement tons and a stowage factor of 58.

About one-third of the palletised sample was loaded in the square of the hatch. These pallets were burtoned out of the square with 5-ton booms and either placed directly onto truck trailers under the hook or placed on the apron and loaded aboard trucks by a 2,000 lb. fork-lift.

Two-thirds of the pallet sample was wing-stowed. Forty-four per cent. of the pallet units were moved from their place of rest underdeck to the square by a 2,000 lb. hard tyre fork-lift. A hand operated pallet jack was used to move 14 per cent. of the wing-stowed sample to the square. The remainder was dragged from underdeck.

A pallet bridle with spreader was used for those units having a lip (wing) and a wire strap was used on the remaining units.

An analysis of the data obtained clearly shows the advantages gained through the use of mechanical handling equipment for the movement of underdeck palletised cargo. By using a fork-lift underdeck, productivity is almost tripled and cost cut by about 60 per cent.

The following conclusions were drawn in connection with discharge:

1. Transporter shipments can be discharged fastest, cheapest and most efficiently.
2. Palletisation is the next best method, if wing stowed and moved by fork-lift to the square.
3. Conventional shipments are most costly, slowest, and least efficient to discharge. Considerable delay was caused by the practice of detailed cargo selection in the hold of the ship.

If no other considerations beyond the discharge function were involved, it would be recommended that:

1. Unitised shipments be used wherever possible.
2. To realise maximum efficiency in discharge of unitised cargo from the wings, it should be so loaded as to permit the use of mechanical handling equipment for movement from place of rest to the square of the hatch.
3. Unitised shipments can be discharged with a 10 man gang for each hook (instead of 15).
4. Transporter shipments are to be preferred over palletised shipments.

Segment 7: Delivery to Warehouse.

This is divided into (a) truck loading and (b) movement to warehouse. The former is concerned with the handling of cargo on the quay after its discharge from the ship. "The quality of the data developed," states the report, "is admittedly poor. It was evident that this phase of the system was relatively unimportant because it was controlled by the rate of ship discharge.

The conclusions drawn were:—

Truck Loading.

1. The unitisation systems are far superior to the conventional system in all respects.
2. Transporters can be handled on the quay, to include truck loading, more efficiently with respect to time cost and manpower, than palletised units.

Movement to Warehouse.

1. At Goose Air Base, transporter cargo is cheaper and faster to deliver by truck than palletised units and the latter in turn are slightly better than loose cargo.
2. The whole cost is too small to be an important factor in the overall comparison of the three systems.

Segment 8: Warehouse Receipt and Storage.

The methods employed at the Commissary Dry-Stores Warehouse adjacent to Goose Bay port are described as follows:—

Palletised Units. These were picked up by fork-lift trucks directly from the trailer bed and carried into the warehouse. Since the units were stored as received, no manual labour was required at all.

Transporters. A crane was used to handle transporters, full or empty, from truck to ground or the reverse. For unloading, the transporters were set next to a ramp and the contents were palletised by labourers.

Loose Cargo. This was palletised at the side of the trailer and carried away by fork-lift. The badly mixed cargo observed (14 to 57 commodities per truckload) presented a complex sorting problem.

Cement. The mechanical part of the handling here was similar to that of the palletised units. Fork-lifts picked up the stevedore pallets from the trailer bed and stowed them 4 tiers high. In addition, the process used a few labourers to pick up broken bags and smooth pallets disarranged by the truck trip.

The conclusions in connection with warehousing were (1) palletised units were handled faster and at less cost than loose cargo; (2) the handling of transporter cargo was slower and more expensive than loose cargo; (3) the transporter affords almost total protection of cargo; palletising has some similar advantage over handling loose. The following table amplifies these conclusions:—

	per net measurement ton		
	Dollars	Manhours	Minutes
Loose goods	0.94	0.48	5
Palletised units	0.12*	0.033	1.4
Transporters	1.67	0.73	10

* Value of pallet not included.

Matters of general interest discussed at the end of the report include:—

Fig. 4. Loading palletised units side-by-side.

Transport of Maritime Cargo—continued

Fig. 5. Fork-lifts stowing palletised units.

Cargo Damage. Quantitative information was exceedingly hard to obtain. This is unfortunate, since the security of transporter cargo (against both pilferage and damage) is a major argument for this system. It was estimated that about five of the 10,000 bags of flour and sugar were damaged in shipment or handling. Protection by palletisation was less absolute, but no evidence of pilferage was noted, and even the two or three palletised units (out of several hundred) which were the most roughly treated in discharge probably sustained less than 10 per cent. cargo damage.

Damage to Palletised Units. Attempt was made to estimate whether the 3/4-in. x 0.035-in. steep straps used to bind the palletised units were too weak, about right, or unnecessarily strong. It may be estimated that they are probably about right. Of a sample of 256 palletised units, 20 had broken straps (8 per cent.), a reasonable breakage rate, not so high that one pallet is likely to lose more than one strap, nor so low that it seems that the strength of the straps might be greatly reduced. In addition, a few pallets were observed in which the glue had shattered but the straps preserved the integrity of the unit.

Labour Performance. As one might expect in an outpost like GAB, the quality of the civilian manual labourers is very poor. They were drawn from the Base Labour Pool, and seemed willing but not very able, and almost without training or initiative. Their inefficiency was accentuated by the limited quantity of supervision available. The effect of this factor will be greater on processes involving much manual labour than on those which are highly mechanised. This introduces a distortion of the relative merits of the systems. As long as conclusions about the systems are restricted to NEAC and other outposts, this distortion can be expected always to be present, and so it can probably be neglected. But if one seeks to compare the systems in other areas (e.g. U.S. to Europe), an error might be introduced.

The conclusions and recommendations of the whole study are presented in two parts.

Part 1. Specific Conclusions Applying to North East Air Command.

Dollar Cost.

1. For subsistence in cartons:—
   (a) Transporters are 41 per cent. more economical than the conventional system if retrograde cargo is available for the return af the transporter.
   (b) Sheathed pallets are 35 per cent. more economical than the conventional system.
   (c) Transporters, even if returned empty to the U.S., are 7 per cent. more economical than the conventional method of delivery.
2. For subsistence in bags:—
   (a) The conventional (loose) system is the most economical.
   (b) Transporters, if returned to the U.S. with retrograde cargo, are slightly more costly than the conventional system.
   (c) Transporters, if returned to the U.S. empty, are by far the most expensive system of movement.

Note: Bagged goods have not yet been successfully secured in palletised units and it is herein assumed that palletisation of such commodities is impracticable at this time.

Manpower Investment.

1. Unsheathed pallets and transporters, if retrograde cargo is generated for the latter, require the least investment of manpower.
2. The sheathed pallet system requires a slightly greater manpower investment than the two systems cited in 1 above.
3. The transporter, when it returns empty, requires the greatest investment of manpower; the conventional system requires the second greatest investment.

Time.

1. Transporters, if retrograde cargo generates for their employment on the return of the vessel to the U.S., deliver a greater volume of cargo per ship per day to Goose Bay than any other system.
2. The pallet and the conventional systems are less effective in delivery capability and register approximately the same performance.
3. Transporters, if they must be returned empty to the U.S., give the poorest ship delivery capability.

Specific Recommendations.

1. Subsistence in cartons or cases should be unitised for shipment to NEAC.
2. Transporters are preferable to sheathed pallets if, and only if, retrograde cargo can be generated for at least about 80 per cent. of the transporters.
3. Bagged goods should be shipped to NEAC by the conventional loose-cargo system if transportation and handling costs only are considered.
4. Bagged goods should be shipped to NEAC in transporters if cargo loss and damage are excessive.

Part II. General Conclusions—Any Overseas Area.

Because the determination of the most desirable system for the supply of any area is, as has been seen, in part a function of the type of package required and in part a function of voyage distance, such decision must depend to a great degree on evaluating the effects of these variables. It is axiomatic that the longer the sea leg, the less important becomes the time spent on berth. Although it is believed clear that for a voyage whose length approximates that of the Norfolk-Goose Bay distance in the NEAC route the acceleration of loading and discharging seems more than to compensate for increased loss of ship cargo space when unitised systems are employed, this obviously need not hold true for other distances. This general consideration of the problem of system selection, therefore, attempts to establish the limits at which one system or the other becomes more or less desirable, conditioned by the requirements for packaging types at various destinations. Inasmuch as system selections must be made on the basis of the special characteristics of each particular case, this discussion of the general area will be confined to conclusions only. The dollar cost performances of the systems are presented and conclusions developed under each of two assumptions:—

A. Dollar Costs.

(i) Cargo in cartons and cases (export pack for loose goods system).

(a) The transporter provides the most economical system of delivery to any destination up to about 5,000 nautical miles from the loading port, provided that the transporter returns with cargo to the U.S.

(b) The sheathed pallet system is slightly more costly than the transporter cited in (a) above, up to about 5,000 nautical miles from the loading port. Beyond 5,000 nautical miles, the costs for transporter (returned full) and the sheathed pallet are so nearly equal that this study cannot distinguish between them. The sheathed pallet system is much less expensive than the conventional system over any distance.

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(c) The transporter, if it returns empty, is less costly than the conventional system to any destination up to about 2,500 nautical miles from the loading port. From 2,500 to 4,000 miles, the measurements in this study are not accurate enough to decide between the systems. Beyond 4,000 miles, the transporter, returning empty, is more costly than the conventional system. Beyond 5,000 miles, it is the most costly of all systems.

(d) The unsheathed pallet system (export-pack items glued and strapped on pallets but not protected with sheathing) is about as costly as conventional cargo at distances up to about 2,500 nautical miles. The differences are smaller than this study has been able to measure. At distances beyond 2,500 miles, the conventional system is less expensive than the unsheathed pallet.

Fig. 6. The Goose Bay Port.

(ii) **Cargo in cartons and cases (domestic pack).**

(a) All systems are about equal in cost up to about 1,500 nautical miles, as far as this study is able to measure, with the exception of the transporter (returning empty), which is by far the most expensive system at any distance.

(b) Beyond about 1,500 nautical miles, the conventional system becomes somewhat less expensive than the unsheathed pallet system and the latter, in turn, somewhat less costly than the transporter (returning full).

(iii) **Bagged Goods.**

(a) The conventional system and transporters returning with retrograde cargo are about equal in cost to approximately 1,500 miles.

(b) Beyond 1,500 miles, the conventional system becomes somewhat less expensive than transporters returning full.

(c) Transporters returning empty are by far the most expensive at any distance.

B. Time.

Considering the comparative performances of the systems from a ship-per-diem-capability to deliver cargo only, the following conclusions are made:—

1. Transporters (returning full) are the most effective of all systems up to a distance of about 2,500 nautical miles.
2. The pallet system is more effective than the conventional system up to a distance of about 1,500 miles.
3. The conventional system is the most effective of all systems beyond about 4,000 miles, followed in order of efficiency by the pallet and the transporter (returning full).
4. The transporter (returning empty) is by far the poorest in ship delivery capability of all the systems, regardless of distance.
5. In the distance ranges not mentioned above, the system capabilities are too close together to make reliable distinctions.

A synopsis of the findings of the whole study is given as follows:

1. For the movement of cartons to NEAC, the cargo should be domestic-packed and unitised in transporters, if there is return cargo for at least 80 per cent. of the transporters.
2. If such return cargo is not available, the cargo should be domestic-packed on sheathed pallets.
3. Bagged cargo should be shipped loose, unless the loss or damage expectancy is excessive, in which case transporters should be used.

This study is certainly a topical one. Handling methods have become so important in recent years that they have a marked effect on packaging, vehicle construction and premises design. It is interesting to note that such operations as those which form the subject of the Research Council's study involve the employment of new handling methods in association with packages, vehicles, premises and ships which were evolved to cope with old ones—that is, with those normally employed when consignments are moved as individual packages and not as unit loads. If it became common practice to make goods ready for transport by palletising them or, where palletisation was not suitable, by placing them in containers, there is no doubt that packaging, transport vehicles, transit sheds, cargo vessels and warehouses would slowly alter in pattern so as to be better suited to mechanical methods of handling.

This is, of course, no new theme. Advocates of the "throughout movement method" have been discussing it and propagating it for several years. The International Organisation for Standardisation, the International Union of Railways, the International Container Bureau and other organisations have been vitally concerned with it and it is inspiring to see the U.S. Research Council taking a step which will once more bring to the notice of shipping and kindred organisations the potential benefits of the new system, the ultimate general introduction of which appears inevitable.

A review of a study of this magnitude cannot give much more than samples of the matter it contains. The original will be found interesting and instructive to many sections of the transport industry and certainly to numerous organisations concerned with port work.

Enquiries concerning the report should be addressed to the Director of the Maritime Cargo Transportation Conference, National Academy of Sciences, National Research Council, Washington 25, D.C., U.S.A.

Timber Handling Conference.

A Conference on Timber Handling, sponsored by the Timber Trade Federation of the United Kingdom will be held at Manchester from 25th to 27th September next. The proceedings will include the reading of papers, discussions and films, related to the special problems of handling timber at all stages from the ship's side, through storage yards, to the ultimate user. The Manchester Ship Canal Company have kindly agreed to provide facilities for demonstrations of machines at work handling timber in the dock area. Several manufacturers of suitable equipment have already offered to co-operate in these demonstrations, so that the full potentialities of mechanisation may be brought out. It is hoped that others will participate so that a comprehensive survey of the range of equipment may be possible.

The Conference is primarily intended for the several sections of the Timber Trade, but the attendance of representatives of other industries having problems of handling timber in bulk, will be welcomed.

Royal Engineers' Transportation Centre Public Day, 1956.

The Transportation Centre, Royal Engineers, is to hold its annual Public Day at Marchwood, near Southampton, on Saturday, 1st September, 1956. Displays and demonstrations will mainly cover the Port Operating and Inland Water Transport sides of the Centre's activities and will include trips on various craft in Southampton Water. There will also be some representation of the Railway activities. Cheap day return tickets will be available from many stations in Southern England and a frequent ferry service will be available between the Town Quay, Southampton and Marchwood.

The Use of Gunite as a Structural Material

A Survey of Developments, 1930-1955*

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Part 1. Introduction

GUNITE is composed of cement and sharp sand mixed together in the dry state, and projected from a pneumatic machine known as a cement gun through a delivery pipe at the surface to be coated. Hydration takes place at the discharge nozzle. The term gunite does not include mortars which are wetted prior to discharge, whether or not a foaming agent is used, as the physical properties of gunite differ materially from all the mortars which are mixed wet before projection.

The most useful structural properties of gunite are its density and the physical bond which it obtains to a suitably prepared concrete surface. It also possesses high compressive and tensile strengths but these can seldom be used in a structural manner.

Materials others than cement and sand can be used when necessary. For example refractory materials are occasionally employed for special purposes but such uses are not structurally significant.

The process of applying gunite has been described so often in previous papers [1, 5, 6, 8] that it is unecessary to repeat a description here. The use of gunite in this country began about 1925. Since then, a considerable volume of experience has accrued regarding the physical properties of the material and also as to its durability. This information is mainly derived from the case histories of structures on which gunite was used. In some cases, accurate information with contemporary drawings, photographs and reports, covers a period of 20-25 years, and in others the information goes back to the date of construction.

It may be convenient to list out some of the main categories of work for which gunite is commonly used.

1. **Water Retaining Structures.** Many old service reservoirs and sewage tanks of masonry, brick and mass concrete construction have been renovated and made watertight with a lining of reinforced gunite. Where foundation defects were present these have been dealt with by pressure grouting or other suitable means. Such works have been described in the technical press and in various papers in the past ([1] etc.). No case has come to notice where this treatment has broken down within 25 years.

Several new mass concrete gravity dams in this country were faced with reinforced gunite from 20 to 25 years ago as a protection against the acid attack of moorland water or against seepage and frost action. The gunite was usually disposed in large continuous sheets, with occasional contraction joints. This practice was open to criticism [1, 2, 3].

In 1937 the Author suggested[1] "that it may be a practical possibility to design a gravity dam with gunite facing in such a way as to introduce economies in the structure as a whole. The question is one that calls for further research." Investigations have since been carried out and a new dam in the Lake District specifically designed for a gunite facing, and embodying all the lessons learnt, has just been completed. Time will show how far success has been achieved.

2. **Water Excluding Structures.** Subaqueous cast iron tunnels have been lined internally with gunite on several occasions. The best known example is the Mersey Tunnel, referred to in the 1937 paper[1].

3. **Protection of Steelwork from Corrosion.** Mild steel coal bunkers in electric generating stations and gas works often suffer severe corrosion from the dilute acids found in wet raw coal, and various materials have been used from time to time to protect the steel from this attack. A 2-in. thick coating of reinforced gunite has proved to be the most satisfactory lining, the reinforcement being physically attached to the plating by suitable cleats. This is now standard practice in the post-war stations built for the Central Electricity Authority and on most industrial installations. It is now nearly 25 years since the Author first used this method of lining bunkers and he can only recall one case where maintenance has been required. The procedure was described in 1937 [1], although improvements in technique have been introduced since then.

4. **Fireproofing Coatings to Steelwork.** Limited use has been made of gunite for encasing structural steelwork to promote fire resistance, chiefly in new installations in the chemical industry.

5. **Linings in Chemical Tanks.** A considerable number of cast iron, steel and reinforced concrete process vessels and tanks have been lined with gunite, giving a relatively long life at a fraction of the cost of alternative materials such as glass, aluminium, etc.

6. **Use in New Building Work.** Frequent trials have been made with gunite applied on some form of light backing for panel wall construction, and the Air Ministry made some extended use of this system during the years 1937-40. It was found, however, that this form of construction could not compete with traditional brickwork either as regards cost, insulation or convenience.

In the early nineteen twenties, gunite was used on some scale for applying thin renderings on houses built of breeze blocks and the like. This was not a great success, as the gunite renderings were too dense and gave rise to internal condensation.

Today perhaps the commonest use of gunite in new reinforced concrete work occurs in the concreting of shell roofs and the protection of the cables on circular prestressed tanks. Here the process is primarily used as a convenient method of placing the concrete and to minimise shuttering.

The foregoing applications of gunite are either not of essential interest structurally or else have been adequately described elsewhere. It is now proposed to deal with the two main developments which are of structural interest. These are the comprehensive reconditioning of reinforced concrete structures, and the strengthening of weakened structures.

Part 2. The Comprehensive Reconditioning of Reinforced Concrete Structures

The Background

The earliest reinforced concrete structures in the accepted sense of the term were built in this country about 1897 and a historical survey has recently been made by Hamilton[4]. This new form construction took root slowly at first, so that the total number of structures built by, say, 1910, was not very high. Thereafter the trickle grew into a flowing stream and then into a flood so that by about 1920, the method was fully established. A good many new firms of designers and of contractors now took up reinforced concrete work. Projects began to be placed on the basis of competitive design, and on the lowest tender irrespective of experience. Margins of cover on the steel were sometimes cut and the upshot is that many structures built in the last 35 years have proved less durable than their predecessors.

By 1925-30 a few of the earliest British structures had begun to show serious deterioration, and spalling of the concrete face. The normal type of deterioration is essentially due to the rusting of the reinforcement. The latter may arise either from lack of adequate cover or from porous concrete, or both. The lack of cover may be due to careless placing of the reinforcement of to inadequate design cover. The quality of the concrete has been dealt with too often in technical papers to need any comment here.

Frost damage and the chemical attack of sea water are seldom critical unless the quality of the concrete is very bad to begin with.

Initially repairs took the form of local patching with the trowel, a useful but short-term expedient. Later, and where the damage

* Excerpts from a Paper read before the Institution of Structural Engineers, London, February, 1956. Type cases of interest to Dock and Harbour Engineers have been reproduced by kind permission.

Use of Gunite—continued

Fig. 1. The Barge Pier, Shoeburyness, after repair in 1930.

was more severe, a covering of fresh concrete was cast on behind shutters. This method proved to have a limited life, as little bond was obtained, atmospheric moisture was not excluded from the reinforcement, the deterioration continued and the patches usually fell off after some years.

It was in these circumstances that American practice was copied and gunite began to be used. The Cement Gun Company Inc., of the United States, formed a subsidiary company in England in 1924, and a contracting service became available. Indigenous specialist companies were formed in 1929 and 1933 and healthy competition gave a spur to technical development.

At this period, the vital importance of cover on the steel was not fully appreciated, and many engineers believed that a fairly light type of repair would suffice. There was a minority, however, that preferred a robust repair, and the technique involved has been described in details by Pearson, who also carried out a number of important structural tests[5].

1930—1939. **A Period of Experiment**

Case 1. The Barge Pier at the School of Gunnery, Shoeburyness is 365-ft. long and 25-ft. wide with a broadened head (Fig. 1). It was built about 1909 and stands in an exposed position at the mouth of the River Thames. By 1929 (after 20 years), severe deterioration had occurred, with extensive spalling of the concrete, laying bare much of the main and secondary reinforcement. The damage was worst on the deck beams and it gradually died out to nothing before mean tide level was reached. Many of the rail-bearers were considered unsafe and strutted. In the worst of these, the stirrups had rusted away completely, and most of the concrete on the tension side had disappeared, leaving the beams acting as flat arches, the main tension bars acting as ties.

In 1930, the upper part of the structure was completely repaired with gunite. All defective concrete was carefully cut away until a sound core was reached. A 3-in. square wire mesh reinforcement of 8 gauge wires was bound round the members, the depressions were filled out and the whole then covered with gunite. The average thickness of the repair was about 2½-in. The War Department then replaced the existing timber deck with a reinforced concrete deck, thus leaving the structure considerably stronger than when it was new. The cost of the gunite repairs was £4,500, and an estimate of the cost of constructing a new jetty was £20,000. The work has been described in detail by Minnis[6]. The methods used were in advance of contemporary practice. The aim was to provide a sturdy repair that would last and that would increase the load-bearing capacity of the structure, and it appears that this aim has been achieved.

A detailed inspection was made in 1955 and the pier was found to be in excellent condition, with a long expectation of useful life before it. A number of minor defects were noted, which could be dealt with by local repairs, but these defects in the 25-year-old gunite bear no comparison with the serious state of the structure prior to repair in 1930.

Case 2. Neglecting normal maintenance works, the next structure of note arose in 1934 at Manchester Docks. The Manchester Ship Canal Company has several long lines of reinforced concrete warehouses built at various times between 1903 and 1926. A number of these sheds have been repaired during the past 20 years by various contractors, but the first shed of all to be repaired presented some features of interest. It was constructed in 1904 and measured 450-ft. x 110-ft. x 45-ft. high (Fig. 2). In 1934, 30 years later, while the interior of the shed was still in first-class order, the external shell showed many defects (Fig. 3) and repairs were put in hand. The work is described in the 1937 paper, 1. Two schemes had been discussed, first a comprehensive overall repair and, second, a thorough repair to load bearing members only and a thin facing coat to the external walls.

The great financial slump of the early 'thirties was still in force and the second scheme was adopted. The work was cut to the essential minimum, and it was not possible to pay much attention to appearance. This building has been kept under occasional observation since, and on the whole the repair work has given 21 years' good service. The structural members which received a heavy repair are nearly all in first-class order, and the main reinforcement has not been attacked, except in one or two instances where the gunite repairs to main beams have failed, and in each case this failure appears to be due to rainwater percolating through the floor above as a result of faulty drainage. However, the light facing coat and isolated patchwork were not so successful and there are a number of instances of the gunite repair coming away from the original surface of the panel. Some additional repairs will soon be needed, and it may not be easy to keep these on a small scale. Other warehouses on the Docks Estate repaired since 1945 have received more elaborate treatment.

Case 3. In 1937, a serious fire occurred in the basement of a reinforced concrete mill building erected in 1914 at Mirfield, Yorks. A number of the main and secondary beams were weakened, and partial failure had occurred. Cracks at 45° had appeared in a regular pattern and some deflection had taken place; some of the floor slabs and column heads were also fairly severely damaged. It is probable that with any other type of construction the mill would have been destroyed. The consulting engineers prepared a scheme for repairs in which additional reinforcement was to be added on one or both sides of the weakened beams, and suitable provision was made for strengthening the remainder of the damaged members. Gunite was then used to build up the members to the larger section (Fig. 4). The floor was carrying heavy machinery while the work was being executed, and a system of primary and secondary strutting was adopted to secure partial transference of load during guniting and until the gunite had had time to mature. The mill remained in production throughout the work.

A repair of a substantial character resulted and the operations have been described in detail[7]. The cost was about one-tenth of the estimated cost of rebuilding the damaged section. An inspection was carried out in 1955, i.e after 18 years, and the work was found to be intact.

Fig. 2. Warehouse at Manchester Docks being repaired in 1934.

Use of Gunite—continued

Fig. 3. Cantilever and secondary beams after defective concrete had been cut away. The deterioration shown is typical of that found in beams on other structures.

A number of other structures were of course repaired during the nineteen thirties by the various specialist firms, but the foregoing were of particular interest, and have been kept under observation to collect data for the future. From 1939 to 1945 the majority of structural engineering work was harnessed to the war effort, and normal maintenance operations were suspended.

The Post-War Years

It will be appreciated that prior to 1939 the annual arisings of reinforced concrete structures requiring repair were few and far between. With the end of the war they increased to a flood. This was due to three causes: first, a great many structures had survived bombing but had been damaged by fire or blast; secondly, there were close on ten years' arrears of maintenance work to be overtaken; and thirdly, the increase in the volume of reinforced concrete construction between 1910 and 1920 now produced a corresponding increase in the normal arisings of repair.

This torrent of remedial works now gave an opportunity for putting new ideas to the test. The pre-war works had already demonstrated that repair work of a substantial nature could be relied upon to last. The war-time experience showed that the drastic remedy was usually the cheapest in the long run.

It was now becoming clear that the most important single factor in durability (whether in new construction or repair) was the amount of cover on the reinforcement. Repair specifications were therefore adjusted to provide increased cover on the fabric reinforcement.

It was also realised that the normal gunite repair may be 100 per cent. sound but it often looks ugly, with uneven arrises and wide variations of colour and texture. If much progress was going to be made, it would be necessary to produce a finish that not only was sound but that looked well—in fact that looked as pleasing to the eye as a new structure. This lead to the engagement of joiners for fixing profiles to secure eyeable lines (not an easy matter, as few joiners will agree to remain at such work for long); and also to the use of cement wash to secure an even colour and avoid unsightly variations.

These changes could not be put into practice by a stroke of the pen owing to the practical difficulties of the immediate post-war period, and several years elapsed before full results were obtainable. The spate of repair work at this time was so great that it is only possible to give some account of the developments by taking the structures in some classified form.

Wharves and Jetties

The repair of reinforced concrete wharves and jetties has been fully described by Minnis, Pannell and Kirk [6, 8, 9]. The works covered by Kirk[9] were carried out during the period 1946-9. It may be useful to summarise the lessons learnt here. The paper covers the repairs of six structures, viz.: two wharves 520-ft. and 500-ft. long, three crane jetties 350-ft., 230-ft. and 200-ft. long, and a fitting-out quay 2,150-ft. long. The structures varied in age from 30 to 38 years prior to repair. Defects were due to two causes, viz.: in the upper part of the structures, to lack of cover on the steel reinforcement, and on the lower part to the impact of ships coming alongside. There was no indication that the chemical action of sea water on concrete was a significant factor in the decay, indeed the evidence is to the contrary. In each case, the life prior to repair was dependent upon the amount of cover provided on the steel in the first instance.

No entirely satisfactory reason has been found to explain the concentration of defects due to corrosion on members immediately under the decking and the reduced occurrence lower down. It was thought to be due to condensation. However, a concrete pier has recently been examined where the timber decking was removed fifteen years ago, but the incidence of defects is unaltered.

The location of damage due to impact is usually at the level of the lower horizontal braces and it attributed to the stiffness of the early designs. The Author has not seen any wharves with a proportion of raker piles or with a thick slab deck, come up for repair.

Case 4. The first wharf mentioned above, 520-ft. long, is at the Eston ore handling plant of Dorman Long (Steel) Ltd., where extensive modernisation work was carried out immediately after the war (Fig. 5). The cost of putting this structure in " as new " condition was £20,000, whereas it was estimated that replacement would have cost about £120,000.

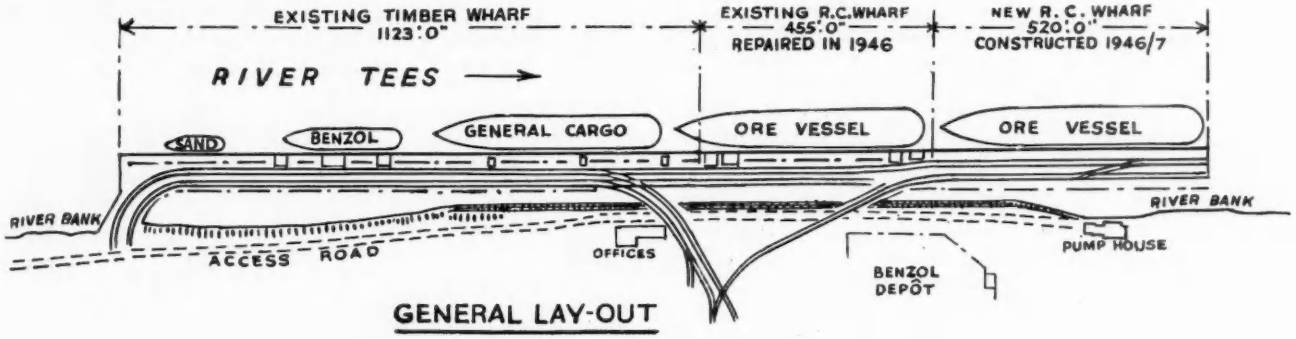
It was recognised that the gunite repair would not make the structure any less rigid and, with heavier ore ships using the berth in the future, the danger of impact damage would be increased. Various proposals for sprung fenders and suspended fenders were discussed but, owing to practical difficulties, it was impossible to provide these, and the original timber fendering was renewed.

Unfortunately, the higher impact stresses have resulted in fresh damage at a low level on the front of the wharf, and in some cases the horizontal braces have conducted the shocks to the rear. A number of the front piles have been fractured, and with them their gunite casings (Fig. 6). The gunite casings on the lower horizontal braces affected represent less than 7½ per cent. of the area repaired in 1946/47, and of this about 90 per cent. is attributable to impact, and 10 per cent. to normal deterioration. Thus the deterioration in the gunite from causes other than impact is about 1 per cent. of the total gunite applied nine years previously. Unfortunately it is nearly all at low level and very difficult to repair. It is now proposed to install some form of sprung fendering, and to repair the structural damage.

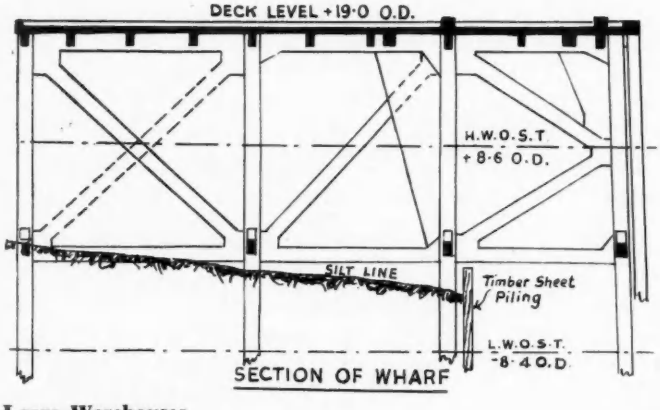
None of the other five structures mentioned above has required any attention since.

Fig. 4. Mill basement after strengthening following fire damage in 1937. The beams have been increased in width to embody additional reinforcement.

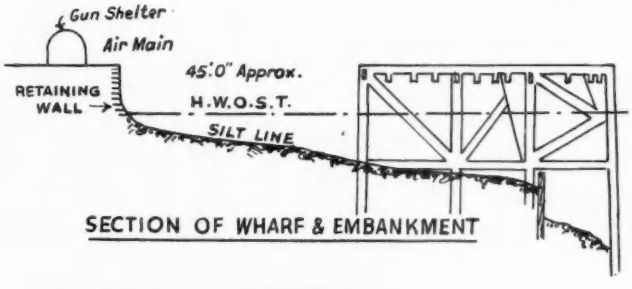
Use of Gunite—continued



GENERAL LAY-OUT



SECTION OF WHARF



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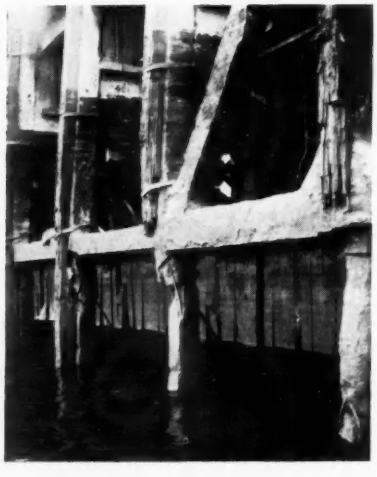

Fig. 5 (above). Eston Wharf, 1946. General Layout.

Fig. 6 (left). Eston Wharf, 1955. Damage to piles due to the impact of vessels.

Large Warehouses

A number of dock and commercial warehouses have been comprehensively renovated in gunite during the past 10 years in the North West and on the North East coast.

Case 5. A large warehouse at Gladstone Dock, Liverpool, was heavily damaged during the war and a considerable section of it required complete reconstruction. This work is described by Mason and Lane[10]. Where the fire damage was slight, reinforced gunite was extensively used to reface the concrete and five cement guns were at work for a long period The work was completed in 1947.

In 1949, another large warehouse adjacent to the first one, and similarly damaged, was dealt with in the same way.

Although the gunite work in these two repairs did not present the interest of the mill at Mirfield, the work in each case was on a far larger scale and obviated a more costly form of restoration.

Case 6. Special mention may be made of a shed at Liverpool, the property of the Mersey Dock and Harbour Board. This shed is 625-ft. long, 95-ft. wide and 60-ft. high, and was built in 1907. Careful maintenance work was carried out regularly by the Board's maintenance gangs and by 1939 the structure was still in excellent condition. During the war some slight damage occurred, mainly from blast, and maintenance work was perforce suspended. By 1951, i.e. after a life of 44 years, the external shell of the shed had got beyond the capacity of normal patching and it was clear that some more drastic measures were needed. Furthermore, the original sliding doors, windows and other fittings were in need of renewal. The interior of the structure was still in excellent condition, apart from some blast damage, local defects and general wear and tear.

It was decided to recondition the warehouse throughout. The external shell was covered with a 2-in. skin of reinforced gunite, with good arris work and an even colour cement-wash finish. One shattered panel was recast in concrete. The platform cantilevers on the dock face, which had suffered severely (mainly from wear and tear) were rebuilt in gunite. Local internal defects were taken care of and some structural defects in the stairways were made good. In fact, a painstaking repair in detail was carried out throughout the whole building. The Mersey Dock and Harbour Board supplied new precast concrete window frames, new doors, hatchway fittings, services and the like, and repaired the flat roof where necessary (Fig. 7).

The gunite work cost £25,000 and the Board's work £23,000, so that the equivalent of a new shed of 166,000 sq. ft. floor area was secured for an expenditure of £48,000. The building was 44 years old when repaired and is now probably good for another 44 years or even more. The comprehensive scale of the repair is in marked contrast to the practice current 20 years ago.

A warehouse of this type would cost over half a million pounds to build today, so that the gunite repair cost about 5 per cent. and the total bill for reconditioning about 10 per cent. of the replacement cost. It is doubtful if a similar result could be obtained by other means.

Tall Grain Silos

Case 7. These frequently show deterioration due to lack of adequate cover on the steel, but one structure of this type is selected for description for other reasons. In 1899 an old brick grain silo in Birkenhead Docks with conventional timber floors was reconstructed internally in reinforced concrete to provide 85 vertical bins.

Use of Gunite—continued

Fig. 7. Warehouse at Liverpool Docks, on completion of repairs and refitting.

The constultant was Mr. L. G. Mouchel, the design drawings were prepared in France, this being in fact one of the first reinforced concrete structures to be erected in this country. The silo has given good service and there is a record of various repairs having been carried out in 1915 and 1928. In 1948 the silo was in need of further attention and a detailed examination was made. The original drawings were still available, and photostat copies were obtained without delay. The supporting columns and beams at the base were in excellent condition after 50 years, but the bin walls were in a less satisfactory state and were cracked in many places. The concrete was porous and friable: it seemed to be oversanded, and a contemporary record is extant showing that there had been difficulty in obtaining cement supplies. An imported cement had been used but it had not been regarded as entirely satisfactory.

Alternative proposals for long-term reconditioning and for short-term repairs were prepared, and the latter were adopted by the owners as it was hoped to replace this building with one of more modern design within half a dozen years. The work consisted of making good defects and lining all the bins with ¾-in. unreinforced gunite; it was carried out in four stages (from 1948 to 1954) and cost £18,000. It is thought that the structure as a whole is now nearing the end of its economic life, as there are signs that the thin coat of strong gunite is tending to tear away from the weak concrete backing.

Few engineers have the opportunity of examining a reinforced concrete structure built in the pioneer days, and this case was of especial interest.

Durability

Unfortunately there seems to be no indication that recent structures are any more durable than those built in the first decade of this century. The Author said in 1937 [1] "It will be appreciated that defects of the type described above are rarely met with in modern reinforced concrete structures. Present-day designers allow for more cover over the reinforcement, and contractors are more experienced in the placing of reinforcement and the precautions to be observed in forming the concrete." These statements were premature and have since proved to be only partly true. Far too little attention is paid to durability. Many structures are now coming up for repair after a life of less than 20 years. There is a vast literature on refinements in design and in construction, but, as regards durability, Hamilton's note [11] stands alone.

Furthermore, very little information has been recorded on the practical aspects of the deterioration and repair of concrete structures, although Lea and Davey[12] and Champion [13] have dealt with some of the more obscure causes of defects.

To sum up the advances that have been made in connection with gunite in 30 years, in 1925 interest was mainly concentrated on the cement gun itself and it was recognised as a useful tool for refacing concrete. Later, attention shifted from the apparatus to the process and the technique attaching to it. By 1935 investigations had moved on to the physical properties of gunite, and the various means of utilising them: the repair of reinforced concrete structures was still largely regarded as a maintenance operation, to be applied locally to defective areas.

At the present day, attention is gradually being transferred from gunite itself to the structure on which it is proposed to use it.

Suppose one has a large warehouse which is showing much deterioration externally but is in very good order internally and which would cost £250,000 to replace today: the outside might be scaffolded and patched for £5,000, which would keep it going for some years, after which it would have to be patched up again. On the other hand it would be possible completely to recondition and refit that warehouse for a sum of £15,000 or £20,000 and leave it good for perhaps 40 or 50 years. Similarly a wharf or bridge might be renovated for somewhere around one fifth of the cost of reconstruction.

There seems to be no reason why the average reinforced concrete structure should not have a life of a century, by complete resurfacing, say twice, in that period. This conception of the complete renewal and refitting of old concrete structures is far removed from the ideas of 25 years ago, and for that reason is selected for treatment in detail as being by far the most important structural use of gunite today.

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(To be continued)

Measuring the Tidal Flow in the River Humber

Electric Potentials Developed by Water Movement

By ROLAND A. COX, Ph.D.

According to Faraday's laws of magnetic induction, when a conductor moves in a magnetic field a potential or voltage is induced between the ends of the conductor, and this voltage is proportional to the length of the conductor and to its velocity. The dynamo works on this principle, the moving conductor being a coil of wire on the armature, generating a voltage when rotated in the field of a magnet. Shortly after Faraday put forward these laws, he pointed out that they should apply to a stream of water, which is a conductor, moving in the earth's magnetic field[1]. Faraday was unsuccessful in an attempt to measure the voltages produced, due to practical difficulties, but with the improved apparatus available to-day later workers have been more successful. It has been shown that in any flowing river there is a potential difference between the water near the two banks which is related to the velocity of the river, and that a meter connected between metal electrodes in contact with the water can be made to measure the flow. M. S. Longuet-Higgins[2] in his paper "The electrical and magnetic effects of tidal streams" gives a review of earlier work and discusses the theory. Recently K. F. Bowden[3] has used the effect to study water flow through the Straits of Dover.

The work to be described was undertaken at the request of the Advisory Committee on Oceanographic and Meteorological Research, to test the possibility of using the earth-induced potentials for giving warnings of storm-surges and abnormal tides. The method may be of interest to those concerned in the construction of harbours and coastal defences in estuaries, as it affords a simple means of measuring water movements in a channel without elaborate or expensive equipment. All that is needed is an insulated electric connection between the two shores of the channel, and a fairly sensitive recording voltmeter.

At the mouth of the River Humber a telephone cable extends from the Yorkshire, or northern, bank to a war-time fort on Haile Sand near the Lincolnshire coast. The narrow channel between the fort and the south bank is shallow and dries at low tide, so that it can be assumed without great error that all water passing along the channel crosses the line of the cable. Through the kindness of the War Office, permission was given to use this cable for taking measurements. The position of the cable is shown in Fig. 1. The southern end of the cable was earthed by connecting the insulated lead to the external armouring, which was in contact with the sea water. At the northern end a recording meter was connected between the lead and earth. This comprised a reflecting galvanometer giving a full-scale deflection on 0.1V and a drum rotated by clockwork once in 24 hours. A sheet of photographic "contact" paper was mounted on the drum, and the spot of light reflected by the meter traced a line revealed by developing the paper. This form of recorder is simple, is relatively cheap to make and needs no power supplies other than an accumulator to run the galvanometer lamp.

Records were taken continuously from 1400 hours on November 30th to 1000 hours on December 3rd, 1955. This period covered the peak of the spring tides, the highest tide being at 1820 hours on December 1st. The records are reproduced as graph A in Fig. 2. The vertical broken lines represent times of high water at Spurn Head, and the horizontal line is the point where there is no net flow in the channel. The section of the curve above this line represents water flowing upstream, and the lower section the ebb. The irregular short period fluctuations are not tidal in origin, but are associated with variations in the earth's magnetic field. They will be discussed later.

The best way to check the accuracy of the curve obtained seemed to be to compute the water transport across the mouth of the estuary from the changing water levels in the river, and the second graph, B, is the computed water flow in the channel. This was calculated by first dividing the tidal part of the river system into sections and computing from the data given in the Admiralty Tide Tables the mean tidal height for each section for each hour during the period of the records. An estimate of tidal water in each section is made by multiplying this height by the area of the section allowing for the variation of this area with the height of the tide adding these figures gives the total tidal water in the river at this time. Finally the difference between successive figures represents water passing Spurn Point during each hour; these differences are plotted in graph B.

Due to the variations of tidal period and height the curve B is slightly irregular. The shallowness of the estuary also distorts what would otherwise resemble a sine wave, giving a curve steeper on one side, while the storage effect of the estuary delays the times at which the water flow reverses. The ebb continues to flow for about an hour after low water, and the flood similarly after high water. In all these particulars the experimental curve agrees well with the computed one. It has been found by other workers[4] that the potentials developed across Dartmouth harbour were in phase with tidal streams in the English Channel outside the harbour, and not those in the harbour entrance. Our results show that in the Humber this is not so, as the experimental results correspond much more closely to the computed times of maximum flow in the channel than to the flows in the North Sea. The weather during the tests was calm and foggy, with no winds stronger than force 3, so that the influence of wind on the records can be neglected.

As mentioned above, the smaller fluctuations shown by the experimental graph are not tidal effects. It has been found that they can be related to magnetic disturbances. Returning to the laws of magnetic induction, a potential is induced when a conductor is moved in a magnetic field. If, however, the conductor is fixed but the strength of the field is altered a similar effect is produced. The strength of the earth's magnetic field is subject to small variations, due mainly to radiations and emissions from the sun and elsewhere, and these variations induce earth currents which are particularly marked in and near coasts and estuaries. The third graph C, in Fig. 2 is a transcript of the record of the horizontal intensity of the earth's field as measured at the magnetic observatory at Abinger, Surrey*; the record has been reduced to the same time scale. Abinger and Spurn are nearly 200 miles apart, so close correlation in the details of the records would not necessarily be expected, but it will be seen that the degree of disturbance along the two records agrees closely, both showing a maximum in the period 1800—2300 hours on December 1st.

This liability of the records to interruption by magnetic disturbances could be a serious handicap in certain types of work Where the investigation was concerned with normal currents in a channel it would be possible to select the least disturbed records

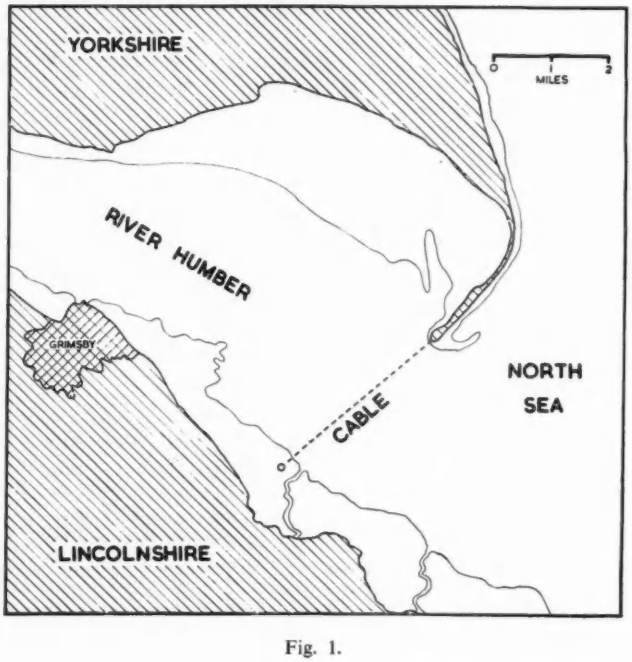

Fig. 1.

Measuring the Tidal Flow in the River Humber—continued

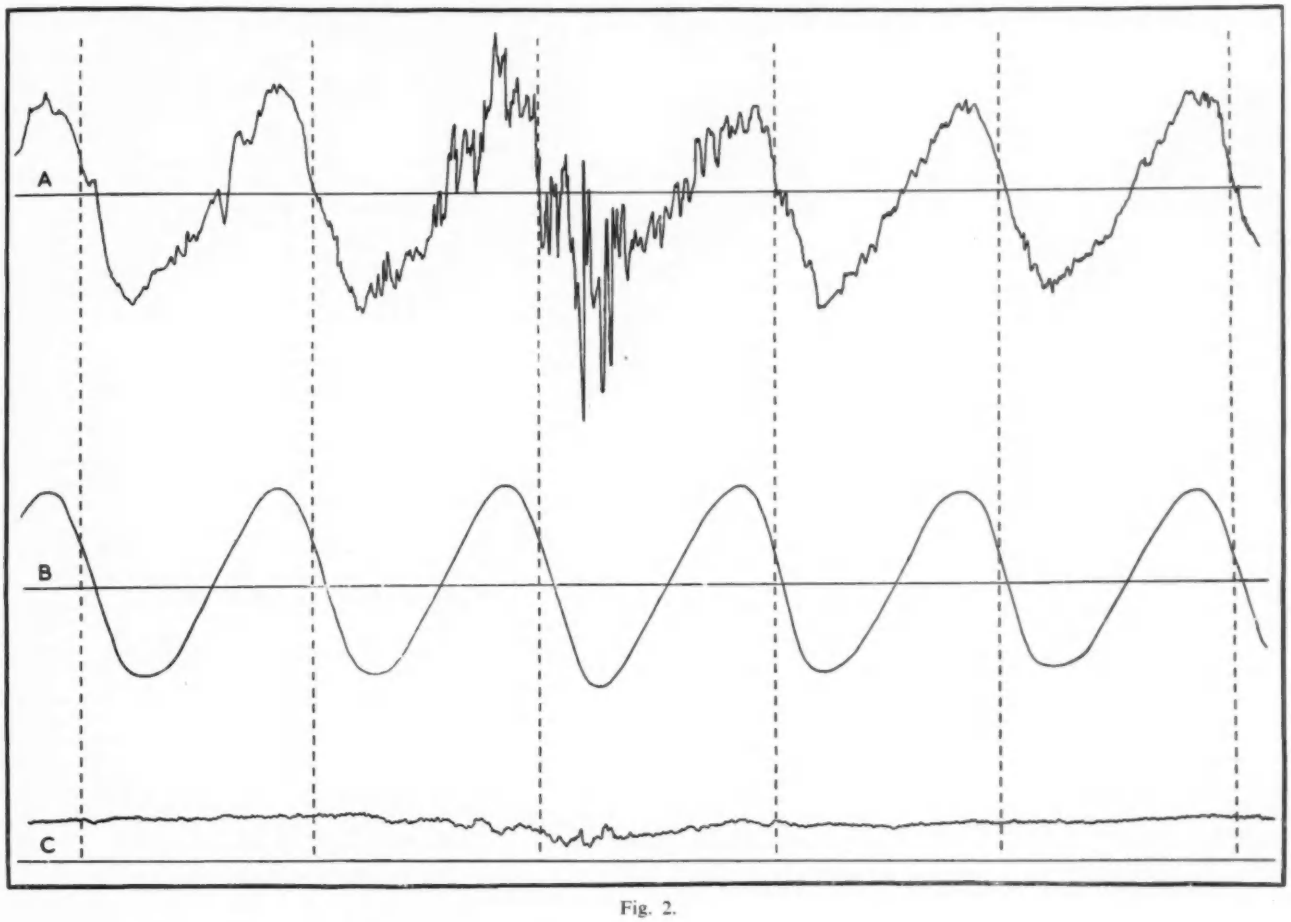

Fig. 2.

and work from these. However, in using the recorder as a warning of storm surges or abnormal streams from other causes such interruptions could clearly not be tolerated, especially as the onset of a magnetic storm could conceivably be misinterpreted as a storm surge. Some means would have to be found of reducing these magnetic fluctuations. N. F. Barber[5] in his paper "The magnetic field produced by earth currents flowing in an estuary or sea channel" found that it was possible to measure the magnetic variations by the flux produced in large coils resting on the sea bed, and it might well be possible to back off such readings against the current record either mathematically or, more conveniently, electrically in the actual recorder, giving an improved record. Bowden, in his work at Dover, found that magnetic variations produced potentials in a land line extending from Dover to Canterbury closely resembling those found in the channel cable. By replacing the simple galvanometer by one having two separate windings to the coil it would be possible to oppose these two outputs, and this should give a record of water flow in which the effect of magnetic changes would be relatively unimportant. If then a direct reading meter were substituted for the photographic recorder an unusual change in the water movements might be detected early enough to give a useful warning.

It should be emphasised that this technique is unusual in measuring the total water transport in a channel; a current meter, in contrast, can measure the flow at a single point only. The two measurements are related but not the same, as the currents vary with depth and position in the channel, and it is sometimes possible, as actually occurs in the Humber, for the tide to be flooding near one bank while still ebbing near the other. It is the overall picture drawn by this instrument which, together with its basic simplicity, represents its potential value.

The author wishes to express his thanks to the War Office, to the Commanding Officer and staff of the Royal Corp of Signals, Northern Command, and to Mr. H. F. Finch, Superintendent, Magnetic Department, Royal Greenwich Observatory, for their help in this work.

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Recent Improvements to Singapore Harbour

It is reported that the new Queen's dry dock at Singapore will be completed within the next month or two. This dock is over 600-ft. in length and 85-ft. in width, and is intended primarily for the accommodation of tankers of up to 25,000 tons deadweight which, in the past, have had to be accommodated uneconomically in the much larger King's Dock. The box flap type concrete gate, which is the first of its kind in the Far East, was manufactured in Great Britain by Sir William Arrol and Co. Ltd. and assembled by the Harbour Board engineers in Singapore under the direction of the makers. The gate weighs 160 tons and folds down into a recess in the dock floor to permit ships to enter or leave. It will be possible to raise or lower the gate in under five minutes and to pump the dry dock in about an hour, making this the fastest working dock in the Far East. It will be served by 3 travelling cranes.

During the past year the Dockyard Department activities included the widening of the Main Wharf at Keppel Harbour, preparatory to reclaiming the lagoon behind this wharf for the provision of much-needed space for future workshop extensions. The open space behind the west end of this wharf has been slabbed over to form a continuous apron between the wharf and the roadway.

Some Notes on Wharf Design

Trends in Construction and Technique*

By J. A. STUART, A.M.I.E.Aust.
(Senior Supervising Engineer, Port of Sydney)

DURING the period 1910-20, the Sydney Harbour Trust laid the foundations for the Port of Sydney as we know it today by building timber wharves and jetties at a rate which greatly exceeded that of any similar period in the Port's history. Without detracting from the great credit due to the men of the time who were responsible for an outstanding achievement, it can be said that it was made technically possible by a number of factors which included the ready availability of adequate timber supplies and the standardisation of details of design.

The timber piles used were of specified dimensions and, with few exceptions, uniformly spaced in rows at 10-ft. centres. Capped with hewn ironbark headstocks 14-in. square by means of a mortise and tenon connection, they were tied together longitudinally by ironbark girders of standard size and spacing and the whole covered with 9-in. x 4-in. brush box decking. Having developed the standard pattern for design, little more than a plan, fixing location and overall dimensions, was required to enable a new wharf to be built. On the construction side, the skill of the wharf carpenters was such that, once the driving was completed, they would "set up" the piles to accurate centering, work and fit the headstocks and girders, and lay the decking—all with a minimum of supervision or direction, but with a great pride in the execution of their work. Probably the greatest responsibilities of the engineer in the field were in maintaining the supply of materials and ensuring that the wharves were built to accurate survey, and, considering the rate of construction, these duties were quite sufficient to keep him fully occupied.

Much of the pattern of wharf construction of 40 years ago still remains, and in Darling Harbour today turpentine piles are being driven in rows 10-ft. apart and capped with timber headstocks 14-in. square.

The skill of the wharf carpenter and his pride in his work are not less than those of his predecessors, but the timber which is the basis of his trade is becoming increasingly difficult to obtain. Turpentine piles are available in small lots only after months of delay and the most diligent efforts of the Board's officers in combing the eastern coast for likely supplies. The specification which once excluded all other hardwoods in favour of hewn ironbark now accepts several substitutes, and even these are not readily available.

This port has been very well served by its timber wharves and jetties. We are fortunate that our natural resources have carried us so far in our maritime development, but, the forests having been depleted to the extent that we can expect only limited supplies from them in the future, we must now look for substitute materials for wharf construction.

The Board will eventually be faced with the task of replacing many of the timber wharves and jetties built in the early period, but will be without the timber resources which enabled them to be built. This will call for an increase in the present rate of wharf construction and the introduction of the most modern techniques of design and construction in order to reduce (a) the cost of construction, (b) the time of construction, and (c) subsequent maintenance charges Let us consider these in turn.

(a) Cost of Construction

Today, we find that a cubic foot of reinforced concrete in a wharf deck costs less than a cubic foot of hewn timber. But, putting the matter in the most general terms, as first-quality hardwood has roughly double the strength of typical concrete (per cubic foot), it is necessary to use the latter in such quantities as to completely negative its basic advantage in cost. Moreover, as the weight of concrete is twice that of hardwood, a wharf structure in concrete has to be strong enough to carry substantially more dead load (or 'self-load") than a timber structure designed to carry the same live load (or useful, superimposed load). The problem, then, is to reduce the cost of concrete or to reduce the quantity of concrete required in a structure of specified capacity. Both can be done.

When we analyse the costs of reinforced concrete in wharf decks built recently by the Board, we find, in some cases, that more than half the money represented by a cubic yard of concrete was spent on formwork As this is only a means of supporting the concrete until it is strong enough to support itself and does not remain as part of the finished work, it is an obvious first point of attack. The cost of formwork is particularly high in wharf work, because the wharf carpenters have to work over water to erect it and then, after the concrete has cured, operate from small scows to dismantle it piece by piece. This latter process is tiring, overhead work which is subject to tidal conditions and difficult to supervise. The dismantled timber has to be reassembled on deck and re-erected in the next wharf-bay ahead in preparation for further concreting. To eliminate this costly procedure as far as practicable, the Board has established a precasting yard at Rozelle Bay, wherein it is proposed to mass-produce reinforced concrete deck slab units to a standard design. They will cure in the yard, be transported to the site of the new work by lighter, and will be lifted into position by means of a floating crane. The cost of handling the precast slabs will be offset by the cheaper concrete produced by the central mixing plant, leaving as a nett gain the virtual elimination of forming costs and a substantial reduction in present concrete deck costs. Construction of the first batch of precast deck slab units weighing 3 tons each was commenced in September, 1954. The process will be extended to units up to 35 tons in weight, and for handling these a floating crane of that capacity is under construction.

To effect economy in the quantity of reinforced concrete required to carry specific loading, the latest principles of prestressing are being applied. This scientific technique has been developed to a high degree on the Continent and in the United Kingdom in recent years, and facilities now exist in Sydney for hiring the necessary equipment. The technique not only results in substantial economy in the use of concrete, which is particularly important in precast work, but it greatly increases the impermeability of reinforced concrete, a factor of prime importance in maritime work.

The layout of the precasting yard at Rozelle Bay lends itself to the effective application of pre-stressing, which is expected to further reduce the cost of the precast work. During September, 1955, the construction of three reinforced concrete beams, each 30-ft. long, to be pre-stressed on the Lee McCall system, was commenced in this yard.

(b) Time of Construction

Passing now from cost to time of construction, we find that the application of the principle of precasting may well effect even more remarkable savings in time. At the risk of over-simplification, one may consider the construction of the deck of a hypothetical jetty 100-ft. wide consisting of timber piles capped with headstocks, and the deck slab spanning 10-ft. between successive headstocks. Assume that a 10-ft. bay is formed up ready for concreting and that the concrete is poured on Monday of week No. 1. For three weeks the concrete is allowed to cure and develop sufficient strength to support itself. On Monday of week No. 4, the carpenters go under the deck in scows, unbolt the supporting timbers, and remove the forming, which is lifted from the water by a crane and deposited on the deck. During week No. 5 this forming is erected in the next bay ahead. During week No. 6, it is handed over to the steel men, who place and tie the reinforcement for the deck slab and

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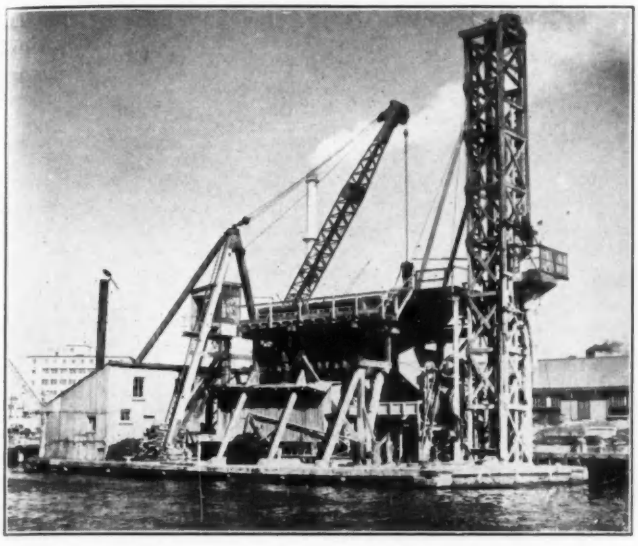
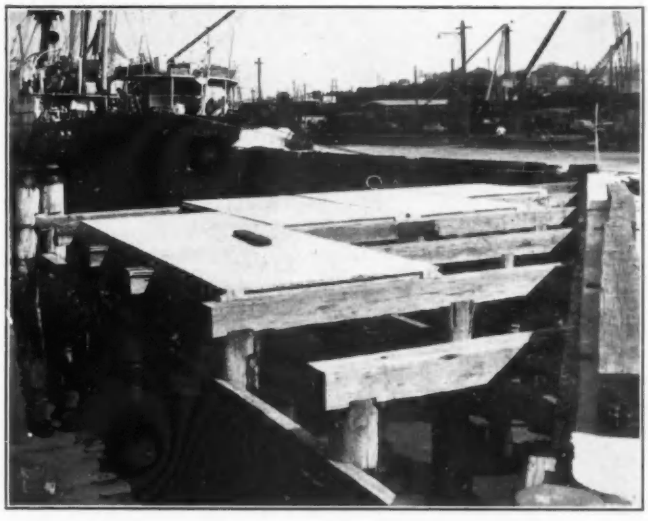
Some Notes on Wharf Design—continued





(Top left). The floating concrete plant first used by the Board to mix and place 18,000 cubic yards of concrete in the fitting-out wharf at Captain Cook Dock, brings bulk mixing and handling facilities to the site of each waterside job. (Top right). Pre-cast concrete slabs were first used in an experimental wharf deck at Rozelle Bay prior to their general adoption for new works. (Bottom left). Pre-cast units were first used extensively in sea wall construction, as here shown at No. 7 berth, Pyrmont. (Bottom right). A small forest of piles is required to support each major wharf structure.

clean out the forms ready for concreting, which takes place on Monday of week No. 7. This is the hypothetical "six-week cycle" which limits the rate of cast-in-situ wharf construction, and it applies whether the work proceeds on a 100-ft. front or whether this is broken into three strips to provide for continuity of operations.

By contrast, precast deck slab units may be made in the precasting yard before the timber piles and headstocks are ready to receive them. While waiting, they would be stacked on edge in racks under ideal curing conditions. When the jetty is ready for them, the lighter in the loading dock would take 30 slabs, each 10-ft. square and weighing 3 tons—90 tons in all—and be towed to the site of the jetty, where the slabs would be lifted by crane and landed in position on the headstocks. Placing of these slabs would deck 30-ft. of jetty on the full width of 100-ft. and should be completed within the week. The laying of mesh reinforcement and 2-in. of topping concrete should be completed in the following week, giving a two-week cycle for 30-ft. of construction on the full width of 100-ft., as against 18 weeks on the cast-in-situ principle.

In a structure such as the one used as an example, pile-driving is the most rapid operation, then the setting up and headstock fixing, and then, a bad last, the casting of an in-situ deck. Although the hypothetical 9-to-1 speed-up in deck construction is not likely to be achieved as an overall acceleration, because of the other operations involved, the adoption of precasting will abolish the "six-week cycle" and eliminate the concrete deck as the factor which limits the rate of construction.

(c) Subsequent Maintenance Charges

The last of the three matters at which design and construction methods are aimed is the reduction of maintenance costs. The burden of maintenance on the existing timber structures must increase enormously as they approach or pass the end of their economic life, and in order to avoid adding to this burden it is obviously desirable that all new structures should be designed with a view to reducing maintenance as far as practicable. This involves not only attention to the selection of the materials of construction, but to the smallest details of design, in which the designer must strive to eliminate all points of vulnerability to corrosion, wear, fatigue, decay, damage or deterioration from any other cause. The goal in design is not the structure that can be easily maintained or preserved, but rather the one that will not require maintenance or preservation at any time.

In foundations, the concrete pile and the Benoto pier will replace

Some Notes on Wharf Design—continued

the timber pile. The Benoto pier has been used, for the first time in Australia, to underpin one of the Board's older wharf structures at Pyrmont, where it has proved itself to be an economic rival of the turpentine pile. To go further, its ability to penetrate a ballast bank without affecting the bank's stability gives it tremendous value in this Port and earmarks it for an important role in reconstruction of existing wharves and jetties.

In wharf shed construction, the use of simple rigid frames of rolled sections at Nos. 7 and 8 berths, Pyrmont, will substantially reduce painting costs. Concrete wall panels 10-ft. square and 2-in. thick made in the precasting yard will clothe the structural framework and will neither require painting nor be subject to the ravages of time and the elements as would timber or iron.

Perhaps enough has been written to indicate the direction in which design and construction methods are developing. Progress may sometimes not appear to be as rapid as we may desire, for many reasons, including the increasing demand upon time brought about by the complexity of modern design. A timber pile neither has to be designed nor have its construction supervised—it grows, is felled and is delivered to the job ready for driving. On the other hand, every component of a concrete pile has to be carefully detailed and its construction and handling supervised at every stage. The same complexity applies wherever reinforced concrete is substituted for timber.

The latest applications of science to engineering have captured the imagination and enthusiasm of the younger generation of professional engineers. It is most gratifying to note that post-graduate lectures in such subjects as " Prestressed Reinforced Concrete " and " Advanced Structural Analysis " are being keenly attended by those younger men in the Board's service upon whom should fall the full impact of the engineering problems associated with wharf-age reconstruction and renewal in later years.

Mechanical Aids for Clearing Waterways

Experiments with Small Dredgers

(Specially Contributed)

British Waterways, faced for some time past with the difficulty of obtaining an adequate labour force to maintain their canals are experimenting with small mechanical dredgers in an endeavour to solve their problems. One particular difficulty has been the dredging of bridge narrowings on the canals. On average, there are about three bridges to every mile of canal and, almost without exception, at each of these bridges there are two bars extending some 50-60 feet from either side.

The bars are difficult to remove, firstly because of their position and secondly because of their hard compostion. Until recently, therefore, they have been tackled only by hand operated spoon dredgers. This type of dredging is slow and present-day labour costs make it expensive and uneconomic.

Two small mechanical dredgers have been tried on canals in the North Western Division to overcome this particular difficulty with modern equipment. One of these, a ladder bucket dredger imported from Holland about four years ago, was used both on the Shropshire Union and the Trent and Mersey Canals. The solid bars at bridges proved to be too much for this novel little machine, and it has now been transferred to the Ashton Canal where it is dealing quite well with silt and the more usual type of canal desposits. This machine was originally designed and developed by Messrs. B. P. de Groot for cleansing and deepening land drainage dykes in Holland, and apart from fitting a British diesel engine it was not modified in any way for canal work in this country. The bucket ladder is belt driven.

Small hydraulic dredger at work.

Mechanical weed-cutting launch.

The second type is a Dinkum Digger excavator, manufactured by Whitlock Bros., of Great Yeldham, Essex, mounted on a Ferguson tractor. The digging, luffing, crowd and slewing operations of this machine are actuated by hydraulic rams and the action is based on the prinicple of a back-acter or drag shovel. The digging action is extremely positive and the machine is very effective.

The tractor and its equipment is moved about the canal in a specially prepared pontoon, but with a restricted beam of 7-ft. for the "narrow " canals, the stability of the pontoon is a major consideration, and this factor governs the method of operation.

After many trials, the correct balance for the barge was obtained, the crucial moments being when the digger is at its full depth and dragging on the canal bottom for a scoopful, and when at right angles to the craft axis, digging or discharging. The suction tends to pull the barge down at present, but later it is intended to counteract this by lowering special hydraulic arms on to the bed of the canal. In the second case, the transverse stability has been achieved by side booms.

These outriggers have been fitted on to the pontoon, where the waterway is sufficiently narrow to permit these to rest on the banks, and in this position it is possible to dredge in the channel, slew the jib and deposit directly ashore.

The tractor in use at the present time has not been modified in any way, and can be taken from the pontoon for general excavation work such as trenching, ditching and levelling.

Where outriggers cannot be used the pontoon becomes unstable

Mechanical Aids for Clearing Waterways—continued

when the loaded bucket is slewed more than a few degrees on either side of the fore and aft axis. Dredgings are then loaded into a flat-bottomed punt as show in the photograph.

The next step in the development of this type of small dredger is to separate the digging equipment from the tractor and to attach it permanently to the forward end of a pontoon with spuds. These spuds are to be hydraulically-operated so giving the stability required for a full slewing arc of 180° or thereabouts. A power unit of similar output to that of the tractor will also be fitted into the pontoon, together with an operator's control cabin where all the controls for digger and for spuds are to be grouped into a single valve-block.

It is hoped that, when fully developed, this hydraulic (oil) operated dredger will prove a reasonably priced, universal and economical machine for narrow and barge canals.

Mechanical Weed-cutting Launches

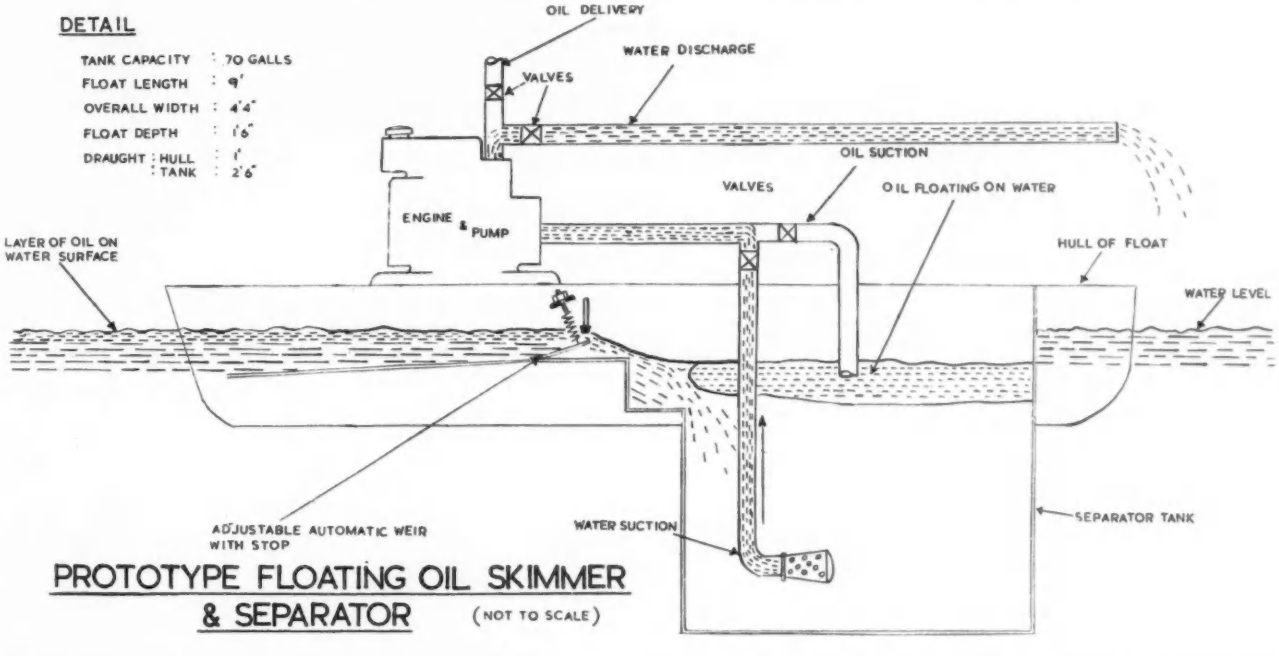
Two mechanical weed-cutting launches, of the standard " B " type, have also been introduced this year into the S.E. Division of of the B.T.C. Waterways. Each launch with Paddle Gear is 21-ft. 3-in. long overall; hull length 17-ft. 3-in.; and 4-ft. wide. They have a weight of 25 cwt. and a draft of nearly 1-ft. and can clear up to an 8-ft. width in one cut, with a maximum depth of 7-ft. In reasonable conditions the weed-cutters can operate at approximately three miles an hour.

A 10 h.p. engine drives both the cutting mechanism and the self-clearing propulsion gear, which is fitted at the fore end. It is manually operated horizontally so that it also acts as a rudder and is controlled by a column and steering wheel. The cutting blades consist of a number of small steel sections riveted to spring backs and mounted in the form of a " V " on the end of an arm on the after end. The cutter arm is lowered to the required depth of cut by a winch and, once the blades have been set, a clutch is engaged causing the arm with the blades attached to be given a backward and forward motion, thereby producing a cutting action.

The power unit is 2-speed, ahead or astern, and drives are by double roller chain. From the gearbox the drive is taken by shafting to the propulsion mechanism and by a shaft through a hand-operated clutch to the cam driven cutter mechanism. Although the launch can cut in both directions in either gear, the general procedure is to work with the cutters leading so making an initial cut. The method of working, however, has always to be governed by conditions.

The machine does not replace entirely manual labour, for the cut weed still has to be cleared from the canal. Where there is movement of water, or favourable wind, the method has been to float a boom or place a boat across the canal downstream or downwind from the cutting. The cut growth floats down against the boom where it is forked clear. Where there is no movement, the cut weeds have to be raked out on the spot.

These small weed-cutting launches are manufactured by Messrs. Howard and Dennis, Ltd. of Bedford.



PROTOTYPE FLOATING OIL SKIMMER & SEPARATOR (NOT TO SCALE)

Removal of Oil from Dock Waters

Skimmer Capable of Collecting all Oils whether likely to Emulsify with Water or not

In the March, 1956, issue of this Journal an account was published of a machine developed at the British Transport Commission's Docks and Waterways Research Station for skimming oil from the surface of dock waters.

It is now reported that a modification of this machine has been developed at this Research Station which is capable also of collecting oils that would be likely to emulsify with the water if they were agitated together in a pump. In this new version of the machine the film of oil, with the minimum amount of underlying water, does not pass through a pump but is drawn by gravity over the automatic weir into a container in which the surface of the fluid is maintained slightly below the dock water surface by a pump which continuously withdraws some of the water underlying the oil in the container. The arrangement is shown in the drawing.

The machine works satisfactorily but since there is more likelihood of significant buoyancy changes with this machine than with the version described in March an automatic adjusting device has been fitted to control the output of the pump in accordance with the fluid level in the container. By this means the changes in fluid level in the container are held within the range in which the automatically adjusted weir operates.

The machine is easy to control and is equally suitable for any oil, whether likely to emulsify or not.

Improvements to the Port of Piraeus

Review of Recent Developments

By PROFESSOR D. A. PIPPAS, C.E., Dr.Eng., M.A.S.C.E.
(Rector of the Technical University of Athens, Acting Chairman of the Port Authorities' Council in Piraeus)

TWO ARTICLES dealing with improvements to the Port of Piraeus have appeared in past issues of "The Dock and Harbour Authority." The first, published in March 1931, was written by Mr. A. Giordano and the second was contributed in 1952 by Mr. J. Andronicos, Director of the Port's Technical Services. The aim of this present article is to describe the improvements which have taken place in the Port during the last five years.

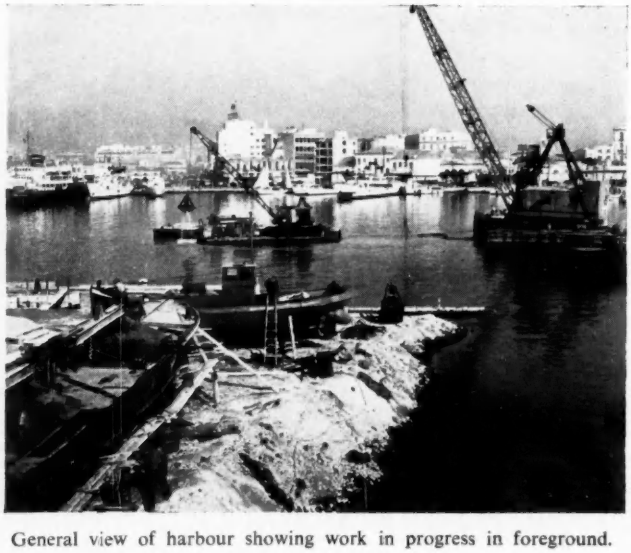
It is necessary to give a brief resumé of the works that have been carried out in the Port, before dealing with those which have been effected recently. Up to the year 1912 the comparatively little constructional work which had been carried out consisted mainly in the building of two external moles (King George's or Krakari and Themistocles Mole), the construction of King Constantine's pier and of quays of small depth averaging between 3 and 6 metres in the central port. Further works comprised the construction of two permanent graving docks and the dredging of the Central Port and the Alon Basin.

In 1923 an authorised Master Plan was approved by a special Committee which was restricted chiefly to the improvement of the northern part of the port. On the basis of this plan the following works were carried out between the years 1924 and 1931. The construction of 1,700 metres of quay walls having a depth of 10 metres of water alongside, 600 metres of a depth of 9 metres, and 400 metres of a depth of 8 metres, also, 700 metres of 3 to 6 metres in depth. Five two-storey sheds were constructed and seventeen 2-ton and four 5-ton electric cranes and two coal gantry cranes installed. One five-storey shed and a 20,000 ton capacity wheat silo with the necessary mechanical equipment were also erected.

The Themistocles Mole was extended by 80 metres, a new mole, named the Saint George's Mole, constructed and a berth for barges using the Port. Dredging was continued in the Central Port and the Alon Basin and other improvement works were carried out such as rock excavations, levelling of the banks, railway installations and electricity supply.

With the execution of this Master Plan the port gradually assumed the status of a modern port, at least in the northern part. The mechanical equipment acquired permitted the efficient handling not only of bulk cargoes, such as coal and cereals, but also of general cargoes and their storage. Because of the limited spending budget of the port the years between 1930 and the commencement of the Second World War saw few harbour improvements. However, proposals for a complete layout of the port were drawn up and, in fact, between 1923 and 1931 ten plans were submitted for approval. Finally, a plan embracing the improvement of the southern and south-eastern sections of the port was submitted by Professor H. Coen Cagli and approved but, owing to the Port's insufficiency of funds, its execution was postponed.

Quay wall under construction in south-eastern area of port.



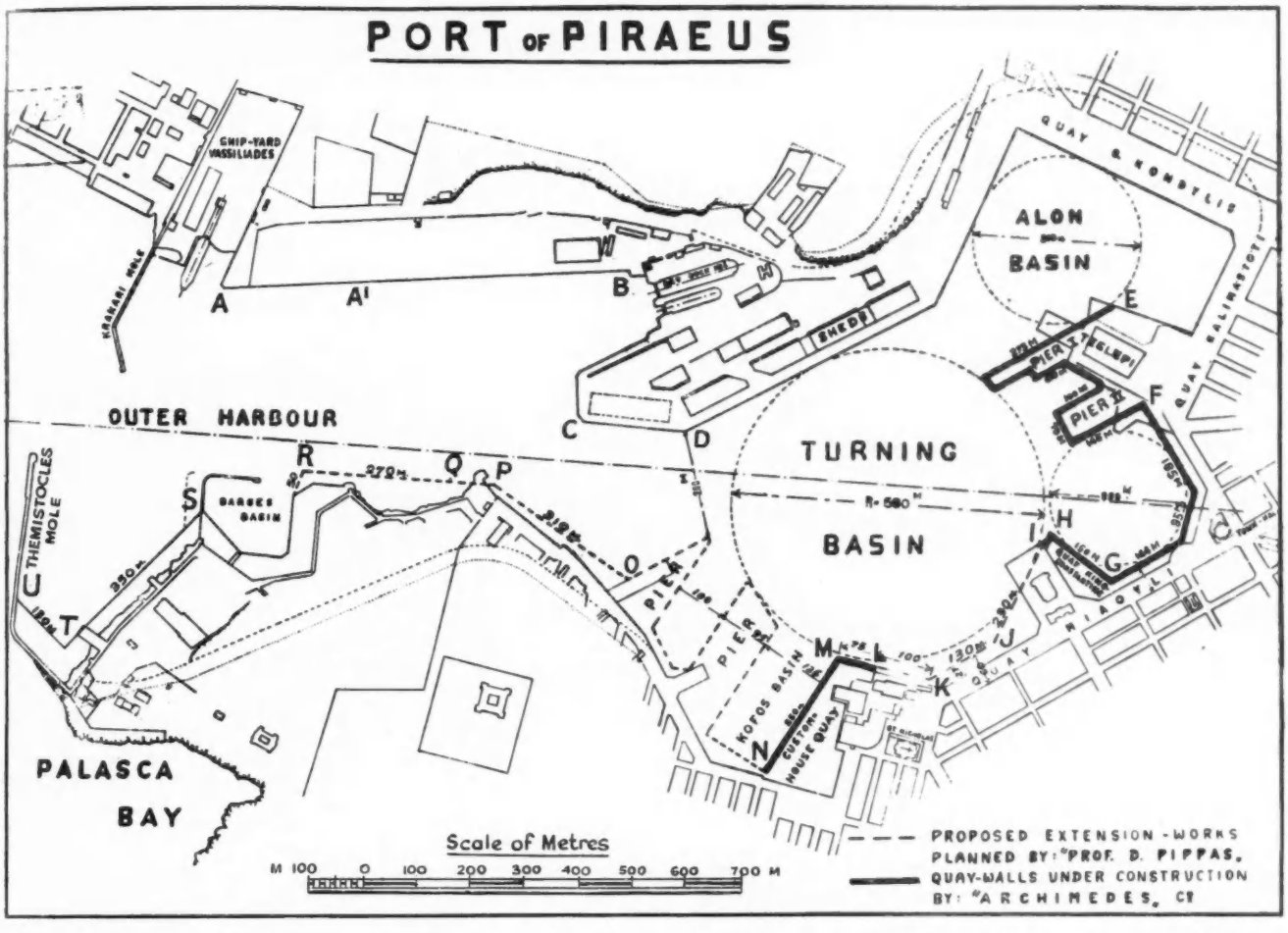
General view of harbour showing work in progress in foreground.

The Second World War not only further interrupted the carrying out of the proposed port improvements, but caused tremendous damage which, even now has only been partly repaired. In the article contributed by Mr. Andronicos to the "Dock and Harbour Authority" in December 1952 a full description was given of the destruction suffered and the works undertaken for the restoration. Among these was the complete reconstruction of the quays C—D in the main harbour, a project which was financed under the American Aid for Greece programme.

Together with the war damage restoration work, Professor Cagli's pre-war plan to improve the port's facilities in the South and South-eastern sections of the port was studied and re-assessed. Between the years 1946 and 1949, therefore, three more studies were submitted in co-operation with British and American specialists. All these were modifications of Cagli's plan, giving smaller turning basins in the Alon Basin and Central Port. Approval was finally given in 1949 to the Andronicos Plan which advocated turning basins of 275 and 470 metres respectively, and the construction of three new piers from the Miaouli quay, giving in all a length of 3,850 metres of new quayage in this section of the port. However, once again this plan could not be carried out because the finances of the Piraeus Port Authority were not sufficient for undertaking new works on a large scale.

In May 1953, however, under the instigation of the Port Authority Council and the General Manager of the Port, Mr. Anastasatos, a newly appointed Port Directorate commenced a reorganisation

The Port of Piraeus—continued



of the port finances. All deficits were eliminated and new financial resources were created for the execution of the necessary improvement works. It was then decided that the plan proposed by Mr. Andronicos and previously accepted by the Port Authority was now no longer sufficient to meet the growing needs of the Port, and it was at this point that the writer of this article undertook the study of the problem.

Subsequently, new plans were worked out taking into consideration the new data available and the re-estimated future needs of the Port. In these plans, emphasis was placed on the necessity of securing a larger manœuvring space for vessels than that envisaged by the Andronicos Plan. It was therefore decided that there should be provided turning basins of 580 metres in the Central Port and 310 metres in the Alon Basin, thus providing the greatest possible manœuvring space and a comparatively large length of quayage.

Furthermore, provision was made in the Plan that the existing traffic layout of the Port should be maintained. Thus the new quays, from point E to point G were to accommodate coastal shipping, the quays G—N the Mediterranean and Trans-ocean liners, the quays N—R the cargo vessels, and the quays N—O either cargo or passenger ships. This Plan was approved and became the authorised Master Plan for the Port of Piraeus (see above).

Before it was approved finally by the Board of the Piraeus Port Authority and the Minister of Public Works, this Master Plan had been carefully studied by a group of competent advisers and thanks are particularly due to Mr. Andronicos and also to Mr. Dallas, the Technical Adviser to the Port, and Mr. Michailidis, Director of the Ministry of Public Works. There was, at this time, sufficient funds at the disposal of the Authority to ensure the carrying out of the larger part of the project.

The Plan provides for a total length of quayage, from E—R, of 4,085 metres. The quays E—F will have a length of 860 metres and depths of 6, 5 and 8 metres; quays F—G a length of 415 metres and 6 and 5 metres depth. These will accommodate the inland coastal lines through which almost the whole of the inland traffic will be serviced (approximately 1,500,000 g.r.t. of arrivals and departures per year) and half the commercial inland traffic (approximately 1,000,000 g.r.t. per annum). The quays G—H (8 metres depth) and H, J. K. M.—N (11.5 metres depth) will berth large liners (approximately 185,000 arrivals and departures p.a.). Quays O—R, with a length of 630 metres and depths of 10, 11.5 metres will accommodate the foreign cargo traffic. Thus there will be twelve berths available for the inland passenger traffic and half the coastal cargo traffic, and space for the berthing of smaller vessels, and also four berths for the Mediterranean passenger ships and two for the Transocean lines. Finally, quays N—O, with a length of 1,160 metres and a depth of 11.5 metres will berth either cargo or passenger ships.

Care was taken to ensure that the construction works did not interfere with the regular working of the port. It was therefore decided to commence work in the south-eastern area of the port on quays E—F, G—I, a length of 1,275 metres and, at the same time, on the quay L—M—N, a length of 325 metres with a depth of 11.5 metres for the accommodation of ocean liners.

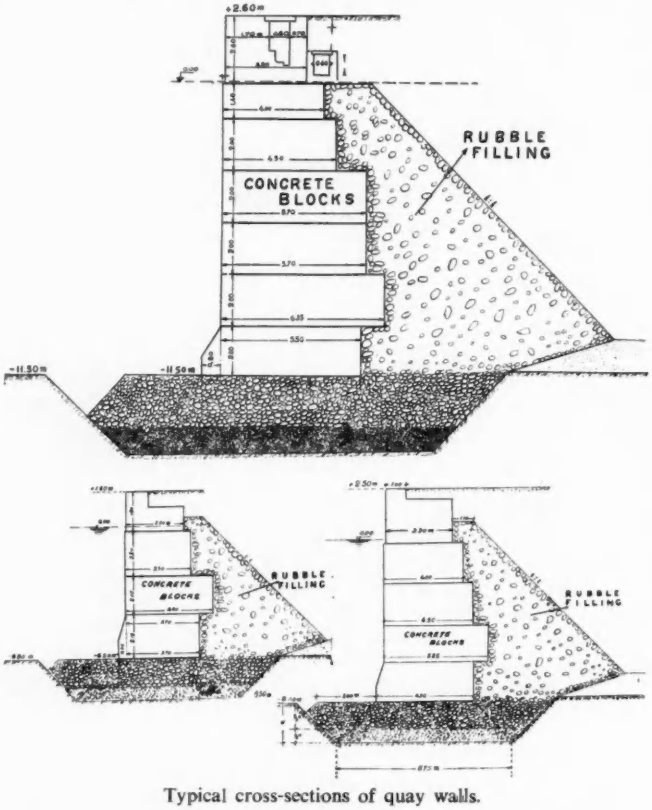
In April 1955 the contract, amounting to some 65,000,000 drachmae (£800,000), for these works was granted to the "Archimedes" Construction Company of Athens, and as soon as they are completed, the construction of the quays I, J, K, L will be commenced. So far the work of the Company is—due to its large equipment and experience—progressing ahead of schedule and it is now expected that the works will be completed one year earlier than intially estimated.

At the same time, another Greek Company was entrusted with

The Port of Piraeus—continued

the execution of works in the outer harbour, at a cost of 22,000,000 drachmae (£275,000), namely, the reconstruction of the remaining section of the quays A—A1, 270 metres long and 10 metres in depth, thus completing the reconstruction of the quayage A—B, and the construction of the quay Q—R, 270 metres long by 10 metres deep. This quay, when completed, will be for the unloading of timber.

All the above mentioned quays are being constructed of artificial concrete blocks of the usual type adopted in Greece, the walls being built upon rubble foundations placed in an excavated trench, with a backing of rubble deposited at a 1—1 slope.



Typical cross-sections of quay walls.

Three types of wall are employed according to the depths of water alongside, as shown in the cross-sections. A similar method of construction to that described above has been used in the past on other quays in the port.

The further construction of quays N, O, P, Q will be undertaken in the future when there is sufficient demand for them and there are adequate funds to finance the work.

In the outer harbour, between the Themistocles Mole and the berths for cargo vessels, U—S, a total length of 480 metres of quayage with a depth of 8 metres will be constructed for the service of ships under repair.

The port of Piraeus will have at its disposal 7,500 metres of berthing space on the completion of the works in 1960, when 4,565 metres of quayage will have been added to the existing 2,850 metres.

Concurrently with the new constructional undertakings, work continues on the maintenance of the port and on restoring the war-damaged northern section of the port. Sheds and warehouses have been built, road and shore land-filling works undertaken and new mechanical equipment installed such as elevators and conveyors. Mention should here be made in particular of the Demag revolving floating crane, which has a lifting capacity of 100 tons. A sum of 40,000,000 drachmae (£500,000) has been spent on these works during the last four years.

The Port of Piraeus is one of the most important ports in the Mediterranean and is also the port of Athens and the largest port in Greece. More than 65 per cent. of the foreign imports are handled by it although only 10 per cent. of the exports of the country pass through it. Further, approximately 50 per cent. of the commercial inland traffic is served by the port.

The following figures show the annual traffic in tons merchandise handled by the port during the last fifty years.

Year	Tons of Cargo	No. of Passengers	Year	Tons of Cargo	No. of Passengers
1905	500,000	—	1938	3,423,000	1,040,000
1909	730,000	—	1939	3,141,000	905,000
1913	1,430,000	—	1948	3,271,000	619,000
1925	2,116,000	—	1949	3,442,000	794,000
1929	2,613,000	—	1950	3,687,000	1,179,000
1930	2,845,000	—	1952	3,640,000	1,428,000
1935	3,167,000	869,000	1953	3,519,000	1,461,000
1936	3,214,000	923,000	1954	3,986,585	1,684,000

The traffic for the year 1954 was the largest recorded to date and was served by 1,667 ships of a net capacity of 7,504,000 tons. Imports totalled 2,865,497 tons and exports 708,829 tons. Goods transhipped amounted to 143,824 tons and supplies to vessels 268,435 tons, making a grand total of 3,986,585 tons.

Management and Operation of the Port

Until 1930 funds for construction and maintenance of the port were provided by the Port Fund, which was restricted to the building and maintenance of the quays and graving docks and the renting of the port zone which was owned by it All other port functions were in the hands of private individuals or organisations. In 1930 was founded the Piraeus Port Authority, which assumed the obligations and rights of the former Port Fund together with the sole exploitation of the ports, i.e., all the cargo handling, the licencing of the sheds and warehouses and the employment of all workmen in the port. Administration by the new Authority has resulted in increased revenue which has been used to defray the cost of the general expenses of the port organisation; chief among these latter being the wages of permanent workers at the port, who numbered some 3,000 at the start but are now decreased to 1,600, with a force of 500 reserve employees.

The installation of further mechanical handling equipment is now the prime concern of the port.

The larger portion of the port is a Free Trade Zone which was established in 1933.

Canadian Harbours

Excerpts from 1955 Annual Report

The twentieth annual report of the National Harbours Board of Canada, states that harbour traffic in 1955 showed a moderate increase over the previous year, the aggregate net registered tonnage being 46,693,486 compared to 45,493,111 tons in 1954, although the number of arrivals was slightly lower, 50,081 in 1955 against 50,891 in 1954.

The aggregate cargo tonnage for the year was 42,414,822, an increase of 1,523,969 tons, or about 4 per cent. Grain traffic dropped from 10,383,781 tons in 1954 to 9,805,710 tons in 1955, a reduction of approximately 6 per cent.

Foreign inward traffic decreased by 492,875 tons and foreign outward traffic increased by 1,214,246 tons compared with 1954. Domestic traffic increased by 187,733 tons and domestic traffic outward increased by 614,865 tons.

Operating income in 1955 amounted to $21,183,718 compared with $20,258,671 in 1954, an increase of $925,047 or nearly 5 per cent. The total was slightly greater than in 1953, the previous peak year.

Maintenance expenses amounting to $2,769,000 were approximately the same as in 1954 and the net operating income was $9,123,422, an increase of $384,235. After taking into account other income and deducting special charges, including interest on debt and reserve for replacement of capital assets, operations for 1955 resulted in a net income surplus of $2,021,863 compared with a surplus of $1,792,113 in 1954, a gain of $229,750.

Manufacturers' Announcements

Radar for New British Railway Vessels

The three new vessels now building for the Heysham/Belfast service of British Railways are to be fitted with Kelvin Hughes Type 2C Marine Radar. Like their predecessors, the new vessels will be fitted with bow rudders since th final stages of their passages are navigated stern first. For this purpose a special radar system has been developed by Kelvin Hughes providing a second display unit which will be mounted on the after navigating bridge for pilotage when going stern first.

Operationally this dual display system is equivalent to having two radar installations. Either one, or both displays can be in use and all the operational controls on each display are completely independent of the controls on the other. The special requirement for clear scanning sectors both fore and aft has been provided by mounting the scanner on a bracket on the foremast at 45 degrees to port of the fore and aft line.

An ingenious arrangement for provision of a signal monitor has been developed at the Kelvin Hughes Research Station on Southend Pier. A special series of deflector plates will be fitted on the foremast. The main purpose of these is to eliminate spurious echoes from the mast, but the upper plate energises the monitor box which is fitted on the mast some 2-ft. above the scanner. A model of the mast and scanner was built at Southend in order to obtain the required results.

New Survey Vessel for the P.L.A.

The motor launch "Havengore" built by Tough Brothers of Teddington for the Port of London Authority has been commissioned for survey work in the River Thames from Erith to the seaward limit.

The vessel is of timber construction, planked in double skin teak having a total thickness of $1\frac{1}{8}$-in. on English oak main members. The deck house is also of teak with the wheelhouse top being constructed of light alloy.

Particulars of "Havengore" are as follows:

Length B.P.	78-ft. 2-in.	Draft Forward	4-ft. 0-in.
Breadth Moulded	16-ft. 6-in.	Draft Aft	5-ft. 6-in.
Length O.A.	85-ft. 0-in.	Main Speed	12 knots

Main Engines Two Gardner 8L3 diesels developing a total ontput of 304 b.h.p. at 900 r.p.m.

The deck house is arranged to house the wheelhouse, office for the senior surveyor, and the plotting room. The plotting room is particularly large and has ample floor space and storage room for plans and instruments, and a plotting table 8-ft. long by 5-ft. 6-in. wide having a portable top faced on both sides with white "Warerite" upon which the master charts can be scribed indelibly. The other main equipment includes a Kelvin and Hughes' echo sounder, Decca navigator, Pye radio telephone, and a Chadburn non-reply telegraph transmitter, the main engines being directly controlled in the engine room.

The light alloy top of the wheelhouse was constructed to give a good all-round view and has a Kent Clear View screen fitted in the window in front of the steering wheel. The vessel is fitted with twin rudders controlled by Mathway steering gear which provides good manœuvrability, and a straight course can be maintained across the tide on one engine set to maintain a speed of three knots for the purpose of accurate sounding.

The main engines are twin Gardner 8L3 diesels each developing 152 b.h.p. at 900 r.p.m. and having a two-to-one reduction gearbox. Electric power is supplied by a Stuart Turner 24-volt, 4-kilowatt 2-cylinder 2-cycle diesel engine. The engine room is well insulated against the transmission of undue noise.

The crew of fourteen, including thre marine surveyors, are provided with comfortable accommodation which is fitted with forced ventilation and an automatically-controlled oil-fired central heating system.

The vessel was basically designed by the Port Authority, while the National Physical Laboratory made model tank tests of the hull, and designed the propellers for a speed of twelve knots.

New Mobile Crane

A new mobile crane, the B.H.C. "Iron Fairy," has been manufactured by the British Hoist & Crane Company, Ltd., Compton, Berks. Expressly designed for lifting and shifting work where the distance travelled is high in relation to the vertical lift, the B.H.C. "Iron Fairy" has a loaded speed of 5 to 10 m.p.h. and unloaded will reach 30 m.p.h. A feature of the crane is the use of hydraulic power for slewing, raising and telescoping the jib, enabling the maximum load of 2 tons to be lifted without raising the jib to its maximum height, thereby allowing greater manoeuvrability. The jib is of two piece telescopic construction actuated by an enclosed double acting hydraulic cylinder. An adjustable link chain tackle head is fitted as standard so as to give immediate hook adjustment. Three small levers are provided for

controlling slewing, raising and lowering and extending and retracting the jib, the speed of each movement being proportional to the speed of the engine. An additional master hand control adjusts the rate of descent of the load from the maximum of 150-ft. per minute to a speed of practically zero. A hydraulic pressure gauge is fitted in the circuit recording the oil pressure and indicating the load on the hook, and an automatic pressure release valve guards against overload. Automatic controls are employed for easy handling of the crane and the driver remains stationary, allowing greater all round visibility.

Manufacturers' Announcements—continued

A Second New "Roll-on, Roll-off" Ship

The Atlantic Steam Navigation Company Limited, of London, operating the Continental Line—Transport Ferry Services—between Tilbury and Antwerp and from Preston to Northern Ireland, have placed an order with William Denny Brothers Limited, of Dumbarton, for the construction of a second new ship. The order for the first of their new ships was placed earlier this year.

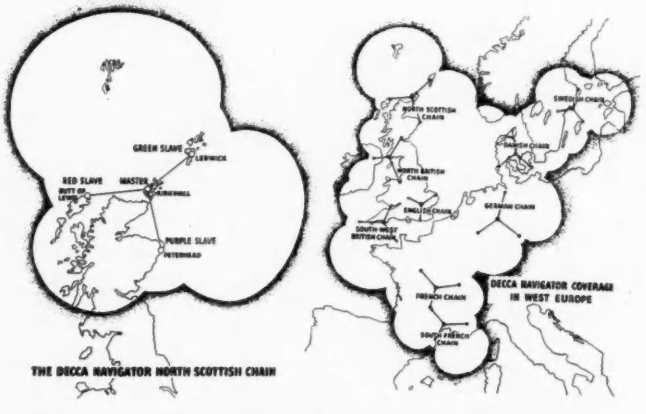
The ship—in every way similar to the one now under construction—is specially designed for the carriage of nearly 100 laden road haulage vehicles, trailers and containers, which will be driven straight on and off the ship, giving a through door-to-door service cross-channel between loading point and final destination.

It is expected this second ship will be available in 1957 and will be placed on the Company's Irish Service.

The Decca Navigator North Scottish Chain

The recent inauguration of the Decca Navigation North Scottish Chain by Mr. J. Henderson Stewart, M.P., Under Secretary of State for Scotland, is an event of great significance. This chain of four stations, located at Peterhead, Lerwick, Butt of Lewis and Kirkwell, completes the high accuracy coverage of the British Isles by the Decca Navigator System, giving a navigational fixing facility of the greatest precision in some of the most dangerous waters around the coasts of the United Kingdom; in the Pentland Firth, for example, a mariner can now be certain of his position within a few yards.

Coverage of this new Chain extends well beyond the Faroes to the North, Scandinavia to the East and well into the Atlantic to the West.



The North Scottish Chain will bring great benefits in safety and economy to the Scottish fishing industry—it is interesting to note that although the largest Atlantic liners avail themselves of the accuracy of Decca Navigator in European waters, the equipment is also carried in the small wooden seine net vessels, using the Decca Navigator to locate and maintain their fishing grounds and to navigate safely and swiftly to and from their harbours; of over 3,000 ships and aircraft using the Decca Navigator almost 1,000 are fishing vessels.

Shipping en route to Scandinavia will find this new Chain of great service, and the "Heron" air ambulances of B.E.A. in common with other local air operators, also will find the Scottish Chain of considerable value in navigating in the remote areas of Scotland.

Of further interest to Scotland is the resiting of the transmitting stations of the North British Chain, one of which will be sited near Stirling. This is part of the trials programme of the long range navigation system—Dectra—across the North Atlantic, to be conducted in collaboration with the Ministry of Supply.

The Decca Navigator System already provides Europe with some two million square miles of accurate navigational coverage, and the opening of the North Scottish Chain marks a further contribution of British electronics to the safety and efficiency of surface and air transport, both at home and overseas.

APPOINTMENTS VACANT

ABERDEEN HARBOUR

Aberdeen Harbour Commissioners invite applications for the following appointments in the office of the Harbour Engineer.

(1) **Assistant Engineer (Mechanical and Electrical)**

Applicants must be qualified mechanical engineers with electrical qualifications or experience, and should preferably have considerable experience in the design, construction and maintenance of harbour installations, such as Pontoon Docks, Bridges, Dock Gates, Cranes and general equipment.
The salary offered is £1,000 rising to £1,100 by annual increments of £25.

(2) **Civil Engineering Assistant**

Applicants should be Corporate Members of the Institution of Civil Engineers or equivalent and should preferably have experience in the design and construction of harbour works.
The salary offered is £850 rising to £925 by annual increments of £25.

(3) **Architectural Assistant and Building Surveyor**

Applicants should have suitable qualifications and good general experience in building design and construction and property procedure.
The salary offered is £850 rising to £925 by annual increments of £25.

(4) **Junior Engineering Assistant**

Applicants should have drawing office experience in general Civil Engineering design.

The salary offered is £415 at age 24 rising at £520 at age 29.

The appointments are subject to the Commissioners' Superannuation Scheme and selected candidates will require to pass a medical examination before appointment.

Applications stating age, qualifications and giving full particulars of experience, together with copies of recent testimonials should be lodged with the Harbour Engineer, 15 Regent Quay, Aberdeen not later than 11th August, 1956.

HYDROGRAPHICAL SURVEYOR required by contractor for work abroad. Applicants should write stating age and full details experience to Box No. 188, "The Dock and Harbour Authority," 19 Harcourt Street, London, W.1.

EAST AFRICAN RAILWAYS AND HARBOURS ADMINISTRATION CIVIL ENGINEERS

The East African Railways and Harbours Administration have a number of vacancies for Civil Engineers for employment on construction or maintenance works. The former cover major harbour and railway construction projects and offer a wide experience in nearly all branches of civil engineering. The latter cover the renewal, investigation, design and maintenance of track, buildings, water supplies, and all civil engineering works on the Administration's railway, harbour, lake ports and road services. The construction and maintenance posts are interchangeable.

Appointments will be either on probation for permanent and pensionable establishment with gross emoluments, depending on age, qualifications and experience, ranging from approximately £1,120 to £1,676 per annum plus free housing or allowance in lieu, or on contract/gratuity terms with gross salaries ranging from £1,350 to £2,500 per annum plus 10 per cent. gratuity on satisfactory completion of contract. Free passages for officer and wife and assistance for children. Generous home leave.

Candidates should preferably possess a University degree or Diploma recognised as exempting from, or have passed, the Final Parts I and II of the A.M.I.C.E. examination and have had a good general training and experience of civil engineering. Applicants wishing to be considered for the more senior posts should have held positions of responsibility. Experience in railway and harbour work would be an advantage but is not essential.

Apply Director of Recruitment, Colonial Office, London, S.W.1, giving details of age, qualifications and experience. Quote BCD/173/014/D23.

THE COMMISSIONERS FOR THE PORT OF CHITTAGONG

SENIOR DREDGING MASTER required. Applicants should hold a Masters ticket (foreign going) and at least 2 years' experience as a 1st Mate (foreign going). Applications from 1st Mates (foreign going) with two years' experience with suction and grab dredgers would also be considered. Salary range Rs. 920/- to 1150/- per month with dearness allowance, dredging allowance and rent-free unfurnished quarters.

Contract for five years; further particulars on application. Apply with full particulars of age and experience to Rendel, Palmer and Tritton, 125 Victoria Street, S.W.1.

TWO ASSISTANT HARBOUR MASTERS required. Applicants should hold a Masters ticket (foreign going) and have at least two years' experience of foreign going vessels.

Preference will be given to those with Masters and/or Pilotage experience. Salary range Rs. 900/- to 1300/- per month with dearness allowance and rent-free unfurnished quarters.

Contract for five years; further particulars on application. Apply with full particulars of age and experience to Rendel, Palmer and Tritton, 125 Victoria Street, S.W.1.